PSYCHOLOGICAL STRATEGIES TO REDUCE
ENERGY CONSUMPTION: PROJECT SUMMARY REPORT

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ABSTRACT

The present report reviews the research conducted in connection with a project to apply psychological theory and procedures to the problems of encouraging residential energy conservation. A major part of the project involved surveys of residents' energy-related attitudes. The best (and only consistent) attitudinal predictor of residents' actual energy consumption was their attitude about thermal comfort. A number of other attitudes that could conceivably have been related to consumption, such as attitudes about the reality of the crisis, were not found to be related to consumption.

Another major focus of the project was on the effectiveness of feedback (that is, giving residents information about their energy use) as an aid to residents' conservation efforts. A series of experiments demonstrated that frequent, credible energy consumption feedback coupled with encouragement to adopt a reasonable but difficult energy conservation goal could facilitate conservation. However, these studies also demonstrated that residents could not be given just any kind of information about their energy use as feedback and that even proper feedback would not lead to conservation in all households. Conditions that are crucial for the success of feedback as a conservation aid are discussed.

Other studies conducted by the project looked at the effect on energy consumption of (1) a device to reduce air-conditioning waste by signalling when it is cool outside, (2) an automatic multi-setback thermostat, and (3) utility companies' average payment plans. A survey of residents' knowledge of their energy use also was conducted.

A list of project-related publications and convention presentations and a bibliography of residential energy consumption feedback studies are included.

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Executive Summary

The social sciences, including psychology, have been far less involved than the physical and engineering sciences in efforts to conserve energy. As a consequence, much less is known about the human (as opposed to the technological) side of the energy crisis, even though it is people who make the decisions to use the machines that consume energy. Only recently have we begun to learn about how people perceive and respond to their "energy environment" and how their attitudes and motivations affect their energy consumption. Nonetheless enough has been learned to indicate that people have an important role to play in any comprehensive energy conservation plan. The present report reviews the efforts of the authors to apply psychological theory and procedures to the problems of encouraging residential energy conservation.

Is energy consumption affected by people's attitudes about energy-related matters? Obviously, many think so. For example, concern has been expressed over the fact that most Americans do not believe that the energy crisis is real but rather that it has been contrived by oil companies. Those expressing such concern argue that if only people could be convinced of the reality of the crisis, then they would behave appropriately and conserve. This argument sounds plausible, but is it true? Do people who think the energy crisis is real use less energy? There are many other plausible but unsubstantiated relationships between attitudes and energy consumption that underlie efforts to encourage conservation. For example, underlying conservation appeals that stress the theme "save energy -- save money" is the belief that if the monetary savings achievable through conservation practices were made salient, people would engage in those

practices. But is the amount of money that people think can be saved through energy conservation practices really related to their energy consumption? By obtaining a better understanding of the relationships between attitudes and opinions and energy use, we would be in a better position to evaluate existing strategies to encourage conservation and to develop new ones.

Three surveys of the energy-related attitudes of 664 people were conducted, two in the summer and one in the winter. Within each study, answers to the large number of questionnaire items were distilled (by means of a statistical technique called factor analysis) into a few basic attitudinal factors or dimensions in terms of which people think about energy consumption. Then, correlations between residents' positions along these dimensions and their actual use of energy (namely, electricity in the two summer studies and natural gas in the winter study) were calculated.

Somewhat surprisingly, a number of plausible relationships between attitudes and energy use were not supported by the data. Residential energy use was not found to be significantly related to people's perceptions of whether the energy crisis is real, that is, a result of dwindling resources rather than of contrived shortages by oil companies. Even though people may differ in their beliefs about the reality of the crisis, they act the same way to perceived availability. (Although attitudes about the reality of the crisis are not related to energy use, they may possibly be related to a willingness to respond to conservation appeals.) Residential energy use also was not found to be affected in any important way by whether residents were optimistic about a technological solution to the energy crisis, whether they think individual efforts can have an impact, the state of

family finances as perceived by husband and wife, or the monetary savings they think could be achieved by daily conservation practices.

There was one "common sense" relationship between attitudes and residential energy use whose existence was supported by the data. By far the best predictor (and the only consistent predictor) of actual energy consumption that was found in these surveys is the residents' attitudes about thermal comfort. The more that one feels that being comfortable in the summer depends on a cool house, the more electricity (for air conditioning) is used. The more one feels that being comfortable in the winter depends on a warm house, the more natural gas (for space heating) is used. This finding, although perhaps unsurprising, has important implications for residential energy conservation programs and appeals; those whose consequences are consistent with people's comfort needs will have a greater chance of success and a greater potential payoff. Rather than being exhorted to make sacrifices for energy conservation, people should be told of the ways they can save energy and be comfortable at the same time.

Survey research represents one approach to learning about the relationships between people and their energy consumption. Another approach taken in this project focused on the immediate environments in which people live that make them more or less conscious of their energy behavior and that facilitate or hinder energy conservation. Consider the problem of modifying residential energy use. First, in residential energy use, we have to deal with a whole family, not just one individual. Thus, we need to develop procedures that influence all family members. Simply showing up at the front door and delivering a persuasive message to the person answering the door won't work. Second, we are concerned with behavior that occurs over time. Consuming energy is a continual process. We need to find ways to

maintain peoples' interest in saving energy over time. Third, consuming energy is not a highly salient activity. As the family goes about its business of getting the kids off to school, cooking, etc., energy is being consumed without much thought about it. How do we make energy consumption in the home more salient without having a crisis atmosphere? So to summarize, we need to intervene in a way that: 1) involves the whole family; 2) maintains interest in conservation over time; and 3) makes salient energy use.

One procedure that meets the conditions just outlined involves feedback, that is, giving residents information about how much energy they used during a recent period of time. Our interest in feedback as a possible conservation aid was stimulated by the large body of psychological research dating as far back as the early 1900's which shows that when people are given feedback, their performance generally improves. This has been found to be the case for a wide variety of tasks ranging from solving simple addition problems to loading logging trucks, from drawing lines of a given length to tracking and ranging tasks involving anti-aircraft guns. Given these findings, it seemed reasonable to ask whether feedback would also facilitate performance when the task involved energy conservation.

Feedback, rather than some other promising energy conservation technique, was chosen as the subject of our first experiments because of our belief that a successful feedback procedure would play a considerable role in any conservation plan. Just as there may be many different diets to lose weight, they all require a bathroom scale to be used frequently to monitor the progress of the diet. We suspected that not only would feedback by itself be a successful conservation strategy, but it would also be a

necessary tool to convince homeowners that a recommended conservation program could work.

Eight experiments involving 602 households were conducted that gave residents feedback about their energy use. In some studies, feedback was given three or four times a week, and in one study it was given continuously. Sometimes feedback took the form of a percentage score that informed a household whether it was consuming energy at a rate greater than, equal to, or less than the rate predicted for it on the basis of its own previous consumption. Sometimes feedback was given in terms of "%-conserved" or "%-wasted" over a preceding two-day period. In one case it was given in terms of the cost of consumption for the next hour if the present instantaneous rate of consumption were maintained. Sometimes feedback was adjusted to take changes in temperature into account. The way in which feedback was displayed varied. In some studies it was displayed by means of plastic numerals dropped into a clear lucite holder attached to the outside of a family's kitchen window. In some studies feedback was plotted on a graph placed in a spot that a family would frequently notice. In one study it was displayed by glowing red digits that were part of a device that had been installed in subjects' homes. Some of the studies focused on the effect of feedback on electricity use in the summer, and some focused on the effect of feedback on natural gas use in the winter. In some studies feedback was investigated along with other independent variables.

Based on the results of these experiments, we have concluded that frequent, credible energy consumption feedback coupled with encouragement to adopt a reasonable but difficult energy conservation goal can be an effective aid to residents in their efforts to conserve. In some studies, groups of families given feedback used from 10% to 13% less energy than control groups.

However, in other studies, no feedback effect was found. Even these "unsuccessful" studies were valuable because they highlighted limitations in feedback procedures and pointed to conditions that were crucial for the success of feedback as a conservation aid.

It is of the utmost importance that the details regarding successful feedback not be forgotten in any follow up work, implementation, or commercialization based on a general conclusion that "feedback works." The truth is that the feedback effect is not automatic. You cannot give residents just any kind of information about their energy use, call it feedback, and expect it to work. And even proper feedback will not lead to conservation in all households.

We now recognize three conditions that are crucial for the success of feedback. First, there has to be an initial commitment to energy conservation on the part of residents. Feedback does not motivate people to conserve. In fact, it works the other way around: only motivated people will make use of feedback. The more conservation that is desired, the more conservation that feedback will help to achieve.

The role that feedback plays in energy conservation is like the role a bathroom scale plays in dieting. If an overweight person wants to reduce, a bathroom scale may be a very useful aid in that effort and may greatly increase the chance that the diet will be successful. For example, if the scale shows that some weight has been lost, the dieter knows that he or she is on the right track and will be encouraged to continue. If the scale shows no loss, or even a gain in weight, the dieter knows that greater effort is needed, that maybe the midnight snacks will have to go. However, if an overweight person doesn't want to lose weight, there is little chance that simply giving him or her a bathroom scale will turn that person into a

dieter. Feedback is not magic in either a food diet or an energy diet. It can make it easier for people who want to conserve to do so, and it can even foster and help maintain this motivation, but it cannot in and of itself turn an energy waster into an energy conserver.

A second critical condition in order for feedback to be effective is that it be given in a form that enables residents to evaluate how well or poorly they are doing with respect to their desired level of conservation. Feedback will be useful to people only when they can learn from it whether their efforts are having the desired effect. The third condition that feedback has to meet is credibility. Homeowners must see a rough correspondence between the feedback and their conservation efforts. In a couple of studies, problems with calculating the feedback led it to fluctuate a great deal. Residents came to doubt that it reflected their conservation behavior, and so they ignored it.

Feedback is a way of providing information that tells homeowners when they are consuming too much energy. Presumably, when feedback indicates waste, homeowners take corrective actions. Thus, feedback is a signal that some energy control action is required. In our feedback experiments, subjects usually were told that their best energy saving action was thermostat control. But there are other ways to highlight the importance of thermostat control and to signal when it should be exercised.

One signal that would be useful would tell homeowners when they could cool their houses without air conditioning by taking advantage of cooler outside temperatures. Usually in the later parts of the day, when the sun goes down, the outside temperature actually drops below the indoor temperature, even with the air conditioner on. It is at these times that it may be possible to maintain a house at a comfortable temperature without air

conditioning simply by opening windows.

To take advantage of this free air conditioning requires that people be sensitive to the outside temperature. One of the rules for the proper use of an air conditioner is to keep doors and windows shut when it is operating. Ironically, this decreases the residents' awareness of outside temperature. To the extent that unawareness of cool outside weather leads to wasteful air conditioning, a signalling device to increase such awareness should be an effective conservation tool.

We developed a device that was wired to the air conditioner and signalled residents (by means of a blinking blue light) when they could turn off the air conditioner, open the windows, and "air condition" their home for free. In a study involving 40 households, the 20 that had the device installed used 15.7% less electricity during the days that were cool enough for the blue light to blink.

Although some people may appreciate receiving feedback and use it to help themselves control their energy usage, others may not want to be bothered with responding to feedback. However, it may be possible to convince this latter group to let an automatic device do the work of saving them energy and money. Day/night thermostats were designed to do just that. They allow the user to drop the temperature of the house by a specified number of degrees for a specified length of time during a 24-hour period. It is usually used by the homeowner to drop the temperature of the house (in the winter) just after the time the family typically goes to bed and to return it to a daytime level just before the time the family typically arises in the morning.

Day/night thermostats clearly lead to a savings in energy, but they do

not take full advantage of the possible savings. They would be more effective energy savers if they allowed users to make a second, even lower temperature setback during a daytime period when they are regularly out of the house. Another problem is that they provide no simple way to temporarily override the cycles when the residents' schedules temporarily change. This greatly reduces consumer acceptability.

Because the thermostat we envisioned did not exist, we built one. The final version of the thermostat permitted both a night and day ("empty house") setback, with separate temperature levels for each setback, and had a flexible override system. The homeowner could choose to override the normal cycle for a desired period of time, and at the end of that period the thermostat would automatically return to its normal energy-conserving cycle. The key point here is that the thermostat would automatically operate to save energy.

Our automatic multi-setback thermostat was very successful. In a summer study there was a 19.4% drop in air conditioner on-time after the thermostats were installed. In a winter study there was a 31.3% drop in gas use. (In each study, an adjustment was made in the results to take into account slight temperature differences in the periods before and after the thermostats were installed.) The greater savings achieved in the winter study is most likely due to more of the participating families being out of the house during the day and, therefore, making greater use of the daytime "empty house" setback. Not only did the thermostat save energy, but resident reaction to it was very favorable. Some families liked it so much that there was some difficulty in getting them to part with it at the end of the study.

In this era of high energy costs, many utility companies have instituted what they call "budget," "equal monthly payment," or "average payment" plans

to soften the impact of large bills. These plans are offered so that payment for electricity for months of peak usage can be spread out over a longer time period. Although energy conservation was not a matter that was pertinent to the institution of the average payment plans, these plans may have an impact on consumption. Of particular concern is whether it is wise, from an energy conservation standpoint, to soften the impact of large bills. Certainly the financial consequences of consumption are less direct under an average payment plan. Also, to the extent that consumers see large bills as signalling excessive, avoidable consumption, it is probably not wise to eliminate this information. As it turns out, customers on the average payment plans do receive information about actual energy use and costs on their bills. However, since they pay a fixed amount each month, this information may be less salient or important to them.

Studies of customer records of two utilities had the same results: the change in electricity consumption from one summer to another was the same for customers who joined an average payment plan (in between the summers) as for those who did not join. It was concluded that given the present context of voluntary enrollment in average payment plans, participation in them had no effect on electricity consumption.

The finding of a number of studies that feedback can facilitate energy conservation demonstrates the importance of residents' knowledge of their energy consumption. The fact that feedback has been able to help people with their conservation efforts may be indicating that their knowledge is inadequate. A survey revealed that this was the case. It was concluded that most people do not have a good idea of how much energy they use in their homes or even of how much they pay for energy. This conclusion implies that the results of studies depending on self-reports of energy consumption

rather than actual measurements might be misleading and should be used with caution.

Another conclusion is that most people have inadequate knowledge about the impact of various energy-using devices on their total consumption. This is a serious problem because residents need such knowledge in order to take effective conservation actions.

A third conclusion that may be drawn from the survey is that many people seriously overestimate the costs and underestimate the benefits of improving the energy efficiency of their homes. In one extensively retrofitted Twin Rivers townhouse, a two-thirds savings in space-heating energy was achieved. Conservation through improved energy efficiency has many advantages as a solution to our country's energy problems. Not only is it effective and economical, but it does not interfere with residents' comfort as do some conservation practices. This is a particularly important point in light of the findings of our surveys of attitudes and energy consumption: resident comfort plays a crucial role in residential energy consumption. The success of efforts to encourage people to improve the energy efficiency of their homes will be jeopardized unless their misperceptions of the costs and benefits of such conservation actions are corrected.

Psychological Strategies to Reduce Energy Consumption:

Project Summary Report

Introduction

The social sciences, including psychology, have been far less involved than the physical and engineering sciences in efforts to conserve energy. As a consequence, much less is known about the human (as opposed to the technological) side of the energy crisis, even though it is people who make the decisions to use the machines that consume energy. Only recently have we begun to learn about how people perceive and respond to their "energy environment" and how their attitudes and motivations affect their energy consumption. Nonetheless enough has been learned to indicate that people have an important role to play in any comprehensive energy conservation plan.

Three pieces of evidence collected by the Twin Rivers project (see Socolow, 1978a) clearly show the importance of the human role in residential consumption. First, in a sample of twenty-eight identical townhouses, variation in energy consumption was found to be as great as two to one. Since these houses are identical in floor plan, position in the interior of a townhouse row, builder, construction materials, and climate, it is likely that most of the consumption variance is due to the different behavior of the people in the houses. Second, in houses where there has been a change in residents, it has been found that the energy consumption of the house with the new residents cannot be predicted from the energy consumption of the same house with the previous residents. Third, even after houses had been successfully retrofitted (with 20-25 percent savings), the variance in energy consumption among the houses remained almost the same as it was before the retrofits took place, and the rank order hardly changed.

These results demonstrate quite convincingly that the energy consumption of a house cannot be completely understood without reference to the people in the house. In the remainder of this report we will review the research that our group has conducted in applying psychological theory and procedures to the problems of encouraging residential energy conservation. First, we will discuss research aimed at finding the attitudinal determinants of residential energy consumption. Second, we will present our research into the conservation effect of providing homeowners with feedback about their energy consumption. Finally, we will discuss miscellaneous "one-shot" studies and surveys bearing on a variety of matters. A list of project-related publications and convention presentations is given in Appendix A.

Attitudes and Energy Consumption

Does it matter what people think of the energy crisis? Obviously many people think that it does. The consumers of polls of attitudes toward energy issues include politicians, government bureaucrats, journalists, and businessmen. The politician may be in search of votes, the newspaperman of a good story, the oil company executive of guidance with advertising campaigns; nevertheless, all share the critical assumption that what people think about energy directly affects how much energy they consume.

Is this assumption reasonable? For example, do people who think the energy crisis is a hoax consume more energy than people who think it is genuine? In spite of the large number of energy attitude surveys that have been conducted (Lopreato and Meriwether, 1976), there is surprisingly little evidence that relates homeowners' attitudes to their actual energy consumption. First, because it is hard to obtain, many surveys have not collected actual energy usage data, assuming instead that homeowners' self-reports of past, present, and future consumption accurately reflected real

energy consumption patterns. But we regard this as an unwarranted assumption. For instance, just after a national fuel shortage, people are likely to say that their most recent fuel bills show savings, because they feel that the interviewer would regard any other answers as unpatriotic. But whether they actually did save is a separate matter. Second, partially because of complex and difficult-to-decipher bills, and partially because until recently energy has been sufficiently cheap so as not to have been worth monitoring, people are often quite unaware of the rates at which they consume energy. For these reasons, until someone documents that there is a strong relationship between actual and self-reported energy consumption patterns, we are skeptical of this assumption.

It is perhaps for the reason that previous surveys have not looked at actual energy consumption that attempts to predict conservation behavior have failed. Murray et al. (1974) were not able to find any statistically significant relationships between reported thermostat reduction or use of major appliances and any nondemographic variables. Curtin (1976) tried without success to predict reported past conservation behavior and expected difficulty of future conservation from fourteen demographic and attitudinal variables. Newman and Day (1975) did collect actual energy consumption data but, because they were primarily interested in describing how consumers use energy, they did not attempt to relate consumption to attitudinal dimensions.

Surveys 1 and 2

In the summer of 1976, we conducted two energy attitude surveys (see Seligman, et al., 1979, for a complete description of the studies and results). Our purposes were twofold: First, we wanted to see whether we could distill from the many varied attitudes that people have about energy a few basic

attitudinal dimensions that reflect people's conceptualizations of energy consumption. Second, we wanted to know whether these attitudinal dimensions relate to actual energy consumption.

The respondents of our first summer questionnaire were fifty-six couples living in Twin Rivers, New Jersey. The respondents are relatively homogeneous: the average husband is in his midthirties, his wife in her early thirties. The majority of couples have one or two children. Forty-two of the couples in the survey sample live in three bedroom townhouses, and fourteen live in two bedroom townhouses. Within each bedroom size, the townhouses are identical in floor plan and have identical central air conditioning systems. In the summer, electricity use for the air conditioner accounts for 70 percent of all electricity usage in these houses.

Notice that by concentrating the survey in Twin Rivers something was lost and something was gained. Because of the relative homogeneity of the residents, it is not possible to be sure that the attitudinal patterns that emerge from an analysis of their data are representative of the national pattern. However, because of the physical homogeneity of the houses, the variance in energy consumption is greatly reduced. Therefore, differences in energy consumption due to attitudinal patterns can be detected more easily.

What attitudes and patterns of thought determine an individual's energy consumption decisions? On initial analysis, it seemed likely that the answer to this question depended on the kind of energy consumption under consideration. Gasoline consumption, for instance, would be likely to relate to a person's perceptions of the convenience of public transportation alternatives, while attitudes determining air conditioning consumption would be more likely to involve dimensions such as the comfort consequences of hotter inside temperatures.

To get an initial fix on attitudes relevant to air conditioning usage, we generated twenty-eight attitudinal questions that represented seven attitudinal categories. The categories were: (1) perceived bother of conserving energy (e.g., "It is just not worth the trouble to turn off the air conditioner and open the windows every time it gets a little cooler outside"); (2) discomfort in conserving energy (e.g., "While others might tolerate turning off the air conditioner in the summer, my own need for being cool is high"); (3) health questions (e.g., "It's essential to my health and well-being for the house to be air conditioned in the summer"); (4) the legitimacy of the energy crisis (e.g., "The energy crisis is a hoax"); (5) belief in science (e.g., "Science will soon provide society with a long lasting source of energy"); (6) morality (e.g., "It is immoral for America to consume 40 percent of the world's energy resources"); (7) the role of the individual (e.g., "To what degree has overconsumption by individuals contributed to this country's energy problem?"). Responses to the questions were made on seven point scales. Except for some background questions, which were asked first, the questions were randomly ordered on the questionnaire.

During the first week of July, potential respondents were telephoned and asked if they would be willing to answer an attitudes-toward-energy questionnaire that had been developed by a group of university researchers. People who agreed were told to expect two questionnaires to be dropped off at their home on a certain day. Wives and husbands were to fill out their questionnaires independently. All of the questionnaires were distributed and picked up from the residents' homes within a two week period. The respondents were also asked to give us their permission to obtain a record of their electricity consumption from the local utility company's files.

All residents agreed. Actual electric consumption (kilowatt hours) for June, July, and August was determined for each couple in the sample.

A statistical technique called factor analysis was used to reduce the respondents' attitude scores to a relatively few attitudinal factors. Four factors emerged. One involved the importance of personal comfort and health in decisions to regulate the use of the air conditioner. People who score high on this factor are not necessarily more concerned with their health and comfort than other people, but they do perceive a close connection between those variables and air conditioner usage. For them, to be cool is to be healthy and comfortable.

A second factor reflected two related concepts: a concern for the effort or bother involved in conserving energy, and a concern with the individual's ability to pay for his energy needs. These two concepts are related in that we can characterize this factor with the statement: "Conserving energy in the home requires a great deal of effort for too little dollar savings." We might name this the high effort - low payoff factor.

Another factor points to the role of the individual in contributing to and alleviating the energy crisis. Individuals who score high on this factor regard the ordinary homeowner as having little or no role in the national energy consumption crisis. Feeling this, a person who scored high on this factor could be quite convinced of the reality of the national energy crisis and still not take steps to conserve, because he would consider his energy savings irrelevant to the aggregate consumption pattern.

The fourth factor that emerged reflected the extent of individuals' beliefs about whether there are real shortages of fuels and whether it is immoral to consume too much energy. We can tentatively label this factor as a concern with the legitimacy of the energy crisis - that is, those who

believe there is a real shortage of fuels believe it is immoral to overconsume.

On the basis of the factor analysis, a picture begins to emerge of how homeowners perceive their energy consumption. The basic considerations seem to involve judgments about effects of conservation on health and comfort, monetary return for one's conservation efforts, the impact of the individual consumer on conservation and the legitimacy of the energy crisis. Since men and women might be educated differently about energy, and since this might be reflected in their having differential attitudinal structures about the abstract topic of energy, separate factor analyses on males and females were conducted. Happily for the simplicity of our data analysis, the same four factors as reported above were apparent for both males and females.

For any individual in the sample, then, a score on each of these four factors can be calculated. To predict a particular house's consumption, one would want to know the factor scores of both husband and wife. Thus eight factor scores (four from the husband and four from the wife) were employed as predictors of each household's summer electric consumption. An overall multiple regression analysis revealed that a total of 55 percent of the variance in consumption was accounted for by the predictors, $R^2 = 0.553$, $F(8,47) = 7.26$, $p < 0.001$. In psychological research, this is a strikingly high attitude-behavior correlation. Thus, our attitudinal variables were very successful in predicting energy use.

The relationship between each factor and energy use was examined by correlating the two spouses' scores on a given factor with consumption. The combined effect of the male and female scores on the comfort and health factor was highly significant, accounting for 30 percent of the variance in actual

electric consumption, $R^2 = 0.301$, $F(2,53) = 11.41$, $p < 0.001$. The more a household perceived conservation as leading to discomfort and ill-health, the more energy the household consumed. Moreover, the health and comfort attitude of the female was more strongly linked to air conditioner usage than was that of the male. This makes sense. Other information we have indicates that the wife is more likely than the husband to be home during the day and to control the energy use during that time.

Scores of the high effort, low payoff factor also significantly predicted consumption, $R^2 = 0.245$, $F(2,53) = 8.61$, $p < 0.001$, as did the households' scores on the role of the individual factor, $R^2 = 0.115$, $F(2,53) = 3.43$, $p < 0.05$. The more energy conservation was perceived as requiring great effort for little monetary return and the less importance attached to the role of the individual in contributing to and alleviating the energy crisis, the more energy was consumed. Scores on the factor involving the legitimacy of the energy crisis accounted for only a trivial proportion of variance, $R^2 = 0.066$, $F(2, 53) = 1.88$, $p < 0.10$.

The results have shown (1) that homeowners' attitudes toward energy can be conceptualized into a few basic factors, and (2) that these attitudinal factors can predict actual energy consumption. Homeowners perceived their use of energy according to their judgement of the effect of energy conservation on personal comfort and health, the effort required to conserve and the monetary payoff for doing so, the ability of the individual to have an impact on the energy problem, and their belief that the crisis is legitimate. Together, these factors were capable of explaining a total of 55 percent of the variance in actual electric consumption. Examined singly, the comfort and health factor, the high effort - low payoff factor, and the

role of the individual factor were significant predictors of energy use. The comfort and health factor emerged as the best single predictor of consumption, accounting for a greater percentage of consumption variance than any other factor.

A second survey of sixty-nine couples was conducted in September 1976 in the same community to attempt to confirm the general results of the first survey (Seligman, et al., 1979). The results of the second survey showed that the same factors reemerged and that together they again accounted for a significant portion of the variance. However, in the second survey the comfort and health factors were the only statistically significant predictors of actual energy consumption.

Survey 3

The two surveys discussed above were conducted during the summer. It is not obvious that the relationships between the attitudinal factors and energy consumption found in the summer would appear in the winter. For example, peoples' beliefs about how being cool in the summer affects their health may be different from their beliefs about how being warm in the winter affects their health. Dr. Spock (1976), for one, argues that in the winter a cool house is more healthful. Moreover, peoples' comfort tolerances for heat and cold may be different. And people may find it easier to keep warm in the winter using less energy (e.g., by putting on a sweater) than to stay cool in the summer without using energy. It is also the case that discretionary use of energy for cooling in the summer is much greater than for heating in the winter. Not using air conditioning in the summer is a real alternative; the air conditioner is a relatively recent invention, and even today many people live without it. Not heating a house in the winter, however, is not a real alternative.

The question of the generalizability of the obtained summer results to

the winter is, in part, an issue of attitude stability over time and, in part, an issue of the relationship between summer and winter energy consumption. Would respondent's pattern of responses to a winter attitude survey be similar to that indicated on the summer surveys? Do the households that use large amounts of electricity in the summer also use large amounts of natural gas in the winter? A third study was conducted in the winter of 1976-1977 to examine these questions. (See, Becker, Seligman, Fazio, and Darley, 1979, for a complete description of the study and results.)

The respondents in this study were chosen from the same planned development in which the Seligman et al. surveys were conducted. The final sample consisted of 55 couples who had been respondents in the second summer survey (hereafter referred to as the "summer survey") and 152 new couples, making a total of 207 couples. Many of the questions included in the present winter survey were adopted, with suitable modifications, from the summer survey. For example, the item in the summer survey, "While others might tolerate turning off the air conditioner in the summer, my own need for being cool is high," was changed to "While others might tolerate lowering their thermostat settings in the winter, my own need for being warm is high." Other questions, from categories not included in the summer survey, asked about the state of the family's finances, efficiency and cost-effectiveness of energy saving home modifications, e.g., adding insulation, and interest in energy-saving ideas and innovations.

Gas consumption during December 1976 and January and February 1977, the three coldest winter months, was determined for each household from utility company meter readings. (All households gave us permission to obtain these readings from the utility company.) The actual consumption period for about half the households was from November 29, 1976 to February 28, 1977 and for the other households from December 3, 1976 to March 4, 1977.

To adjust for the slight difference in the dates of the consumption period, consumption for each household was divided by the number of degree-days in its consumption period.

The attitudinal factors that emerged in the winter survey were in large part the same as those found by Seligman et al. in their summer surveys. Importantly, the factors linking comfort and health perceptions to energy use appeared in both the summer and winter surveys, showing that these concerns are not specific to the heating and cooling seasons. Factors that are not necessarily related to a particular season also appeared in both surveys. These factors were: optimism with respect to a solution (perhaps scientific) to the energy problem, the legitimacy of the energy crisis, resultant savings from conservation efforts, and the impact of the individual on consumption and conservation. Not only did similar factors appear in both studies, but significant correlations were found between comparable summer and winter factors for the 55 couples who took part in both surveys. These factors included comfort [$r(108) = .55, p < .001$], individual's role [$r(108) = .37, p < .001$], legitimacy of the crisis [$r(108) = .31, p < .001$], optimism/belief-in-science [$r(108) = .30, p < .001$], and health [$r(108) = .16, p < .001$]. The significant correlations are evidence for the stability of those attitudinal factors over time. One new factor emerged that concerned the state of the family's finances and was characterized by questions that were not included in the summer survey.

The comparison of the summer and winter comfort factors bears on more than the matter of factor stability. The fairly large positive correlation between the summer and winter comfort factors indicates that people who find it difficult to tolerate warmer inside temperatures in the summer also find it difficult to tolerate cooler inside temperatures in the winter and,

conversely, those who can tolerate warmer summer temperatures can tolerate cooler winter temperatures. Since both these summer and winter factors are positively correlated with energy consumption (see below), it would seem that there is a negative correlation between the width of people's thermal preference ranges and their residential energy consumption. In other words, one might expect to find that the bigger energy users are people with narrow ranges of acceptable temperatures and that the smaller users are those with wider ranges.

As in the summer studies, factor scores were derived for both husbands and wives in each of the 207 couples. The 14 factor scores (7 male and 7 female) were used as predictors of each household's actual winter gas consumption. A multiple regression analysis revealed that a total of 18.2% of the variance in consumption was accounted for by the factors taken together, $R^2 = .182$, $F(14, 192) = 3.06$, $p < .001$. The multiple regression of both spouses' comfort-and-convenience scores on actual gas consumption accounted for 7.6% of the variance, $R^2 = .076$, $F(2, 204) = 8.37$, $p < .001$. The less the couples were willing to put up with being chilly or inconvenienced in order to save energy, the more gas the household consumed. The more optimistic the spouses were about a solution to the energy crisis, the more gas they used, $R^2 = .049$, $F(2, 204) = 5.30$, $p < .01$. And the more they viewed a chilly house as having a deleterious impact on family health in the winter, the more energy they used, $R^2 = .033$, $F(2, 204) = 3.44$, $p < .05$.

The amount of variance in gas consumption explained by the attitudinal factors in the present winter study ($R^2 = .182$) was considerably less than the variance in electricity used explained by the factors in the summer survey ($R^2 = .592$). Fortunately, because 55 couples responded to both the summer and winter surveys, a direct comparison of the results was possible. Regression

results based only on this subsample showed that about twice as much consumption variance was accounted for by attitudinal factors in the summer as in the winter. To some extent this difference may be due to the difference between the ranges of summer electricity and winter gas consumption. In the area where the present study was conducted, and indeed in most of the country, the range of electricity consumption in the summer (mostly for air conditioning) is greater than the range in gas or electricity consumption in the winter (mostly for space heating). When summer and winter consumption were transformed to the same scale (by multiplying winter scores by the ratio of mean summer consumption to mean winter consumption), the range in summer electricity consumption among the 55 households who participated in both surveys was 2.13 times as great as the range in winter gas consumption. The relationships between the winter factors and winter consumption may have been smaller than those between the summer factors and summer consumption because they were attenuated by the restricted range of winter gas consumption compared to summer electricity consumption.

The reason for the difference in the ranges of summer and winter consumption is that for each unit change in thermostat setting, within the typical range of settings, the proportional change in summer electricity consumption is much greater than the proportional change in winter gas consumption. In the houses involved in the present study, 1°F thermostat in the summer can affect electricity consumption as much as 7%-8%. A 1°F thermostat change in the winter affects gas consumption only 3%-4%. (See Socolow and Sonderegger, 1976). This difference, in turn, is a consequence of the fact that in the climate where the study was conducted, the average indoor-outdoor temperature differences are greater in the winter than in

the summer.¹ It is interesting to note that in a different climate where indoor-outdoor temperature differences are greater in the summer than in the winter, the reverse would be true, namely that each unit difference in thermostat setting would have a greater impact on winter consumption than summer consumption. In that case the range of winter consumption scores would be greater, and the relationship between that consumption and attitudinal factor scores might be greater than the same type of relationship in the summer. Thus, attitudinal factors conceivably are better predictors of summer energy use in, say, the Midwest or Northeast, and better predictors of winter energy use in, say, Florida or the Southwest.

In the winter study there were four factors that were not significantly related to winter gas consumption. People's perception of the legitimacy of the energy crisis was not significantly correlated with their energy use in either the present survey or in the two Seligman et al. surveys. This consistent finding argues against trying to convince people to save energy by arguing that the energy crisis is a permanent problem of finite resources. Even though people may believe very differently about whether the energy crisis is real, they may act the same way to perceived availability. When shortages appear imminent, as in the 1973-74 Arab Oil Embargo and during the severe 1976-77 winter, people tend to conserve. When energy supplies are believed to be available for the foreseeable future, people tend not to conserve. Moreover, even people who believe the energy crisis is real now may believe, for example, that solar energy will solve the problem in the future.

Winter gas consumption is also not significantly related either to the state of family finances as perceived by the husband and wife or to the monetary savings they think could be achieved by daily conservation practices.

This is somewhat surprising in light of economic models of behavior. It also has important implications for the content of appeals aimed at promoting everyday energy-saving behavior, such as turning the thermostat down and keeping it down. Many conservation campaigns have stressed the theme "save energy--save money." Unfortunately the amount of money that can be saved by daily conservation efforts (e.g., turning lights off when they are not need) is fairly small in absolute terms. It may be that for many people such savings do not justify the costs in terms of reduced comfort and convenience.

Finally, the factor concerning the individual's role in the energy problem was not significantly related to gas consumption in the present study; however, it was a significant predictor of electricity consumption in Seligman et al.'s first summer survey but not in their second.

A major result of these surveys is the finding regarding the importance of the residents' attitudes toward his or her comfort as a determinant of actual energy consumption. Attitudes about thermal comfort and energy use are by far the best (and only consistent) predictor of residential energy use. Residents' need or desire for comfort can have a substantial impact on consumption because space heating and cooling comprise the biggest components of residential energy consumption in the winter and summer, respectively. This finding has important implications for residential energy conservation programs and appeals; those whose consequences are consistent with people's comfort needs will have a greater chance of success and a greater potential payoff. Rather than being exhorted to make sacrifices for energy conservation, people should be told of the ways they can save energy and be comfortable at the same time.

There are a number of things that conservation campaigns can encourage people to do that will conserve energy without sacrificing comfort. Engineering research has shown that two-thirds or more of winter energy use in an ordinary home can be saved without affecting comfort by making various modifications to the house, such as installing insulation, window shutters, etc. (Beyea, Dutt, and Woteki, 1978; Sinden, 1978). An automatic multi-setback thermostat also can be effective (see pp. 60-65). Psychological research has shown that around 15% of summer electricity use can be saved by alerting residents to times when they can conserve and remain comfortable by engaging in a few simple behaviors like opening the windows and turning off the air conditioner (see pp. 55-59, and Becker and Seligman, 1978). There are other simple ways to conserve without affecting comfort. For example, by putting on a sweater a person can be comfortable at lower temperatures and by using an electric fan (rather than a more energy expensive air conditioner) a person can be comfortable at higher temperatures (Rohles, 1978). The basic point is that saving energy does not have to mean sacrificing comfort. The challenge for social science, industry, and government is to communicate this message effectively to the public.

Helping the Resident to Conserve: Feedback Research

Survey research represents one approach that psychologists have taken to study the relationships between people and their energy consumption. As we have seen, surveys can tell us a great deal about the characteristics or attitudes of people that are important for energy consumption. Another approach to the problem is to be less concerned with individual differences in attitudes and habits and to be more concerned with the immediate environments in which people live that make them more or less conscious of their energy behavior and that facilitate or hinder energy conservation.

Consider the problem of modifying residential energy use. First, in residential energy use, we have to deal with a whole family not just one individual. Thus, we need to develop procedures that influence all family members. Simply showing up at the front door and delivering a persuasive message to the person answering the door won't work. Second, we are concerned with behavior that occurs over time. Consuming energy is a continual process. We need to find ways to maintain peoples' interest in saving energy over time. Third, consuming energy is not a highly salient activity. As the family goes about its business of getting the kids off to school, cooking, etc., energy is being consumed without much thought about it. How do we make energy consumption in the home more salient without having a crisis atmosphere? So to summarize, we need to intervene in a way that:

- 1) involves the whole family; 2) maintains interest in conservation over time; and 3) makes salient energy use.

One procedure that meets the conditions just outlined is feedback, giving people frequent information about their rate of energy use. Consider a typical house: Appliances are run, hot water is used, the air conditioner cycles and the homeowner has no idea how much energy he or she is using. The utility bill comes at best once a month and often is an estimate rather than based on actual use. Clearly, the homeowner lives in an information deficient energy environment. But what would happen if we gave the homeowner more information about his energy consumption, if we closed the feedback loop between the homeowner and the house?

Our interest in feedback as a possible conservation aid was stimulated by the large body of psychological research dating as far back as the early 1900's which shows that when people are given feedback, their performance generally improves. This has been found to be the case for a wide variety

of tasks ranging from solving simple addition problems to loading logging trucks, from drawing lines of a given length to tracking and ranging tasks involving anti-aircraft guns. Given these findings, it seemed reasonable to ask whether feedback would also facilitate performance when the task involved energy conservation.

Experiment 1

Our first study to test this idea involved 29 Twin Rivers homeowners who lived in identical three-bedroom townhouses. (See Seligman and Darley, 1977, for a complete description of the study and results.) The homeowners were randomly assigned either to a feedback group or to a control group. For three weeks in August, 1975, research assistants read the electricity meters each weekday and, from Tuesday through Friday, gave each feedback household information about its consumption. The feedback indicated whether the electricity it had consumed in the previous day was equal to, less than, or greater than its predicted consumption. (Predicted consumption took the temperature of the feedback period into account.²) This information was conveyed as a percentage score (of actual over predicted consumption) and was displayed by means of plastic numerals dropped into a clear lucite holder attached to the outside of the sliding glass patio door. A score of "80%," for example, meant that actual consumption had been 80% of predicted consumption, indicating conservation. A score of "120%," on the other hand, meant that actual consumption had been 120% of predicted, indicating excessive use. These numbers could easily be seen from kitchen and family area.

The same day the feedback began, each household in the feedback group received a letter explaining the feedback procedure, that is, how predictions of their electricity use were made and what the numbers in the lucite device

meant. The letter also focused the homeowners' attention on air conditioning; they were told that in the summer, the largest use of electricity was due to air conditioning. The control group was sent the same letter, except for the part dealing with the feedback procedure. Therefore, summarizing the similarities between conditions, all households, regardless of condition, had their electric meters read five days a week and were told that they were in an energy study, that air conditioning was the largest use of electricity, and that we hoped they would reduce their air conditioning usage. Thus, both demand characteristics to reduce electricity consumption and information received about how to do it were the same for both groups. The feedback group differed from the control group in that it received the daily information about its consumption and an explanation of how that information was presented.

The results showed that providing homeowners with feedback about their energy consumption can be an effective way to help them conserve energy. In the month before feedback began, both groups consumed electricity at approximately equal rates (daily average of 68.3 kWh for the feedback group and 69.1 kWh for the control). During the feedback period, the feedback group reduced its consumption to 48.6 kWh/day whereas the control reduced its consumption to only 54.3 kWh/day. That is, during the feedback period, the group receiving feedback used 10.5% less electricity than the control group. This difference was statistically significant, $F(1,21) = 4.81$, $p < .04$. (The fact that the control group also reduced its average daily consumption can be attributed largely to the change in weather -- it was cooler during the feedback period than in the previous month.) Interviews with the residents afterward indicated that people did in fact use the feedback to help them conserve.

For example, one woman said "I felt I could see what I was doing. When the numbers went over 100 I really tried. I kept the shades down to keep the sun out."

Experiment 2

Although in this study, and in others, feedback has been found to be able to facilitate energy conservation, it was not at all obvious how it had such an effect. One claim has been that feedback facilitates performance by motivating a person to try harder or persist longer at a task. However, it is unlikely that feedback in itself is motivating in the sense of supplying a person with the drive to conserve. Indeed it would be very surprising to find that simply giving energy consumption feedback to someone with no real desire to conserve could turn that person into an ardent conservationist. What is more likely is that feedback plays a secondary motivational role. Given that a person has a desire to conserve, feedback can lead to increased conservation efforts by showing that actual conservation is below the level the person wants to achieve. It is in this way that feedback can trigger increased effort; by informing a person as to the actual level of his or her performance, feedback signals when more effort is needed in order to reach a desired level. With greater effort directed toward improving performance, performance often improves.

If feedback operates in this way to facilitate conservation, then along with feedback, the conservation goal that a person has is a crucial factor in the conservation that is subsequently achieved. To test this idea, a study was conducted in which some residents were asked to set a goal of reducing their electricity consumption by 2%, an easy goal, while others were asked to set a goal of reducing their consumption by 20%, a difficult goal. (See Becker, 1978, for a complete description of the study and results.) Half of the households in each of these conditions were given feedback three

times a week showing where they stood in relation to their goal. A fifth group of households was not asked to set any goal and was not given any feedback. They served as a control group against which any conservation achieved in the four experimental groups could be measured. One hundred families who were willing to participate and who were not planning to take a vacation during the treatment period were randomly assigned to the 5 conditions with the constraint that there be 20 families per condition.

The feedback in this study was calculated by determining a household's predicted electricity consumption (taking weather into account) for a two or three-day feedback period and comparing this to its actual consumption. More specifically, the difference between predicted and actual consumption was given as a percentage of predicted consumption. For example, if a household was predicted to have used 50 kWh but actually used 45, this was plotted as 10% conserved.

Feedback was given three times a week, every Monday, Wednesday, and Friday for about one month during part of August and September, 1976. It was displayed to the families on a chart that was held in a clear plastic envelope taped facing inward on the sliding glass patio door. (See Figure 1) It could easily be seen from inside the house. Families not receiving feedback got different charts that were marked with an "X" each time the electricity meter was read. This was done to control for the attention paid to the feedback groups.

Group means for consumption during the feedback period are presented in Table 1. As predicted, the group that was assigned the difficult conservation goal and that received feedback consumed the least electricity. Indeed, according to an analysis of covariance, this group was the only one that used significantly fewer kilowatt-hours than the control group,

Figure 1. Example of feedback chart used in experiment 2 for the difficult goal-plus-feedback group.

$F(1, 94) = 9.22$ $p < .005$. (Analysis of covariance adjusts the during-treatment scores on the basis of pretreatment scores in order to minimize the effect of pretreatment differences among groups. See Keppel, 1973, pp. 477-500.) It used 13.0% less. The difficult goal-no feedback group used only 1.3% less electricity than the control group. The easy goal-plus-feedback group used 4.6% less, and the easy goal-no feedback group used 1.2% more than the control. This pattern of results supports the hypothesis that the motivational effect depends on the presence of both a difficult goal and feedback about performance in relation to the goal.

Additional insights into how feedback can lead to energy conservation may be obtained by further examining the differences between the feedback and no feedback groups within each level of goal difficulty. As mentioned above, of the two groups given the difficult goal (i.e., conserving 20%), the one receiving feedback used 13.0% less electricity than the control group, while the one not receiving feedback used only 1.3% less. When a goal is difficult, a good deal of effort must be made to achieve it. Even without feedback, people know this to be true and, consequently, may exert themselves to an unusual degree. However, even though they may be trying harder than usual to perform well, without feedback there is no way for them to know whether their efforts are sufficient to lead to the desired high level of performance. Since the effort required to perform at levels far above those that are familiar is usually stressful (or in some way aversive), a pressure constantly exists to drop back to easier levels of effort (and performance). This may lead to an over-estimation of the amount of effort actually expended. For example, people new to jogging are often surprised to learn that the very fatiguing two miles they estimated they just ran was really only a mile and a half. Without feedback, it is easier for

Table 1

EXPERIMENT 2: AVERAGE DAILY ELECTRICITY CONSUMPTION (in kWh) DURING THE
FEEDBACK PERIOD

Descriptive Statistic	Difficult Goal		Easy Goal		Control
	Feedback	No Feedback	Feedback	No Feedback	
Raw score					
<u>M</u>	35.2	36.9	40.1	41.4	38.8
<u>SD</u>	15.2	7.2	11.6	10.1	12.6
Adjusted score ^a					
<u>M</u>	34.7	38.0	39.4	40.3	39.9
<u>SD</u>	8.3	3.6	4.1	5.1	4.3

Note. n = 20.

^aThe adjusted score represents average daily consumption during the treatment period adjusted to take into account differences among the groups in pretreatment consumption (from June 1 to August 8, 1976). The adjustment was obtained by the analysis of covariance method (see Keppel, 1973, pp. 477-500).

people with difficult goals to maintain counterproductive misperceptions about the amount or adequacy of their efforts. This may lead to their putting out less effort than that really needed and, consequently, to their performing less well than they are able or want to perform.

The difference in performance between the 20% goal-plus-feedback group and the 20% goal-no feedback group also provides evidence against the argument that what has been interpreted as a feedback effect is really a Hawthorne effect. In both groups the demand characteristics and amount of contact with the subjects were identical, yet a large difference in consumption still occurred.

Of the two groups given the easy goal (i.e., conserving 2%), the one receiving feedback used 4.6% less electricity than the control group, while the one not receiving feedback used 1.2% more than the control. Although the 4.6% reduction in consumption was not statistically significant, it is not trivial. In a follow-up questionnaire given after the study, 4 of the 20 households in the 2% goal-plus-feedback group admitted to having set a more difficult goal after discovering how relatively easy it was for them to achieve a 2% reduction in consumption. None of the households in the 2% goal-no feedback group reported setting a higher goal for itself. This finding illustrates another way in which feedback may lead to increased conservation. Feedback may demonstrate to those with only a tentative commitment to energy conservation that saving energy is not as difficult or painful as they may have thought, and thereby encourage them to conserve more.

Experiment 3

The evaluation of whether a household is using too much, too little, or the right amount of energy depends on the reference point that is chosen. Present usage can be compared against past usage, as was done in experiments 1 and 2, or it can be compared against other households' usage. A third alternative is to compare a household's present usage against a standard based on the house's physical characteristics and the weather.

For all three types of comparisons, feedback can be given. Self-comparison feedback has already been discussed above. Social-comparison feedback can inform residents about how much energy they consume relative to others living in similar houses with similar appliance packages. In this kind of feedback, the effects of weather on consumption is controlled, because each house is exposed to the same weather (except for differences in orientation which affect wind and solar flux and have a small effect on consumption relative to the temperature). The most important distinction between the social-comparison feedback and self-comparison-feedback is that people are being compared to other people and not to predicted consumption based on their usage at an earlier time. In what may be called objective-comparison feedback, residents are told how much energy they actually have used compared to how much they were predicted to have used on the basis of engineering models of the energy use for their house. Weather-related variables constitute an important part of the model.

During the winter of 1975-1976, we conducted a feedback experiment to (1) see if the results of experiment 1, involving electricity consumption in the summer, could be replicated for natural gas consumption in the

winter, (2) examine the relative effectiveness of different kinds of feedback, and (3) test whether feedback is a more useful conservation strategy than either (a) directing the homeowners' attention toward the amount of his energy usage or (b) disseminating information about how to conserve energy in the home.

Building on what we had learned from the first experiment, we were able to develop a more sophisticated and easier to implement feedback procedure. In the homes that were to receive feedback of any kind, we installed a digital clock that recorded the amount of time the furnace was on. The clock was attractive and therefore the homeowner did not mind having it situated in the kitchen near the telephone. The clock could be reset to zero by pushing a button. Since our clock, unlike the gas meter, was easy to read, it became possible to enlist the aid of the homeowner. Every evening (six days a week) between January 24 and March 13, 1976, each homeowner was called by one of our staff and asked to give the reading on the clock and to reset it to zero. The research assistant used the information to make the appropriate calculation and then announced the resident's feedback score. In this way, we were able to eliminate the costly, sometimes inaccurate, and cumbersome procedure of having a research assistant go around to each house to read the gas meter and to post the feedback score. The already existing telephone lines were used as our communication network and our digital clock became a more accessible and informative gas meter.

In order to examine the questions posed earlier, we randomly formed six different groups of homeowners, drawn from the same community as in the summer study. Over 125 residents whose homes used natural gas only for space heating volunteered to participate. The first group received self-

comparison feedback, the same kind as was given in experiment 1. This was daily information about how their rate of gas usage compared to their predicted rate of usage, which was derived from a previous month's modeling period. The residents in this group, as well as in the two other feedback groups described below, were asked to record their feedback scores over time on a chart given to them.

A second group was provided with social-comparison feedback. Homeowners in this group were informed each evening about where they stood in relation to the rest of the group (i.e., their rank order), with regard to their day's gas consumption. Presumably the motivation to do better (i.e., conserve more) than one's peers should result in the whole group lowering its consumption. It should be noted that since all the homeowners lived in similar houses, they would be more likely to ascribe differences in consumption between themselves and others to differences in lifestyle than to differences in house construction.

Homeowners in a third feedback group were given objective-comparison feedback. They were told each evening the extent to which their daily gas consumption was more or less than the amount predicted for their house. The prediction, the residents were told, was based on heat load calculations specified by theories of physics. A fourth group that had a clock installed and was called each evening was the attention group. Residents in this group were only asked to tell us the clock reading each night. Their clock readings were not translated into self, social, or objective-comparison feedback. The purpose of this group was to control for

- (1) the amount of attention paid to the feedback groups and
- (2) the increased salience of energy that was created in the feedback groups.

A comparison of the consumption of this group with the feedback groups would show the effects of feedback beyond the effects due to attention and salience.

A fifth group acted as a control for dissemination of knowledge about conservation techniques. Members of this group received a handbook, prepared by the Center for Environmental Studies, about how to conserve energy (e.g., what to insulate, how to adjust various valves, the importance of keeping filters clean, and the like). This group was not contacted daily. Residents simply received the handbook, left at their door with a letter of explanation, at the same time as calling began for the other groups. Since the three feedback groups also received the handbook, this group controlled for the conserving effects due to information.

A sixth and final group served as a control for all the groups. This group received no special treatment of any kind. However, since every household that agreed to participate had its gas meter read weekly, members of this group did know, of course, that their gas consumption was being monitored by the experimenters. Thus even this group may have conserved somewhat compared to a group that would not have been aware of an experiment taking place.

The results showed that all treatment groups conserved compared to the control group (see Table 2). However, since an analysis of covariance did not find the differences in consumption among the groups to be statistically significant, questions concerning the relative effectiveness of the three feedback procedures and the extent to which attention and knowledge play a role in conservation cannot be answered unambiguously from these data.

Table 2

EXPERIMENT 3: AVERAGE DAILY GAS CONSUMPTION (in 100 cu. ft.) DURING THE FEEDBACK PERIOD

<u>Descriptive Statistic</u>	<u>Self Comparison Feedback</u>	<u>Social Comparison Feedback</u>	<u>Objective Comparison Feedback</u>	<u>Clock Control</u>	<u>Knowledge</u>	<u>Control</u>
Raw score						
<u>M</u>	4.21	4.17	3.87	4.08	4.30	4.47
<u>SD</u>	0.78	0.95	0.86	0.95	0.80	1.01
<u>n</u>	24	21	24	23	16	17
Adjusted score ^a						
<u>M</u>	4.10	4.14	4.18	4.17	4.15	4.36
<u>SD</u>	0.39	0.34	0.34	0.50	0.32	0.47

^aScores adjusted by removing the effect of covariate, average daily consumption during the pretreatment period (December 13, 1975 to January 24, 1976).

Nevertheless, it is interesting to compare the percentage difference in consumption between the self-comparison feedback group and control group in this study to the equivalent percentage difference in experiment 1. In experiment 1, the (self-comparison) feedback group used about 10% less electricity than the control group, and in this study the self-comparison feedback group used about 6% less gas than the control. The interesting point is that both of these reductions in consumption can be achieved by the same amount of change in thermostat setting, about $1\frac{1}{2}$ to 2°F . Each degree change in thermostat setting has a smaller effect on gas consumption in the winter than on electricity consumption in the summer. (See Footnote 1.) Thus it is possible that the feedback was leading to the same amount of conservation behavior (i.e., thermostat-setting change) in this study as in experiment 1, even though it was not resulting in as much conservation. If this is true, it means that the effects of feedback should be more demonstrable on electricity consumption in the summer than gas consumption in the winter (except in very hot climates -- see page 14).

Experiment 4

Because the results of experiment 3 were not clear cut, it was decided to attempt to repeat the experiment in the summer with the same subjects. Unfortunately because of the large number of people who planned to take vacations during the summer, it was not possible to rerun all six groups, because the resulting sample size would have been too small. It was decided to rerun the self-comparison feedback, social-comparison feedback, clock control, and control groups because we thought the self and social-

comparison feedback groups were the most fruitful to pursue, and we needed the two control groups. A second decision had to be made about whether to keep people in their winter conditions or to rerandomize. The two advantages of keeping people in their winter conditions were: (1) we would not have to remove and reinstall the clocks from most of the houses; this is a timely and costly procedure, (2) people would already be familiar with their previous experimental treatment (especially in the feedback and clock control groups) and their previous experience might facilitate conservation. Because of these reasons, we chose to keep people in their previous condition. People in the objective-comparison feedback group who wanted to participate in the experiment in the summer were randomly assigned to one of the three conditions that required a clock, because they still had their clocks in place. The people in the knowledge group who were willing to participate further were assigned to the control group, because they did not have clocks installed, the control group did not require it, and the knowledge handbook that they had received in the winter was largely relevant to winter conservation.

Of the 125 subjects in experiment 3 who were asked to continue their participation, 54 subjects were eventually lost; 40 said they were going on vacation, and 5 that they were no longer interested; data collection was incomplete for another 6 subjects, and equipment breakdowns occurred in 3 cases. Of the 40 who said they were going on vacation, 31 were in self, social, and objective-comparison feedback conditions in the winter, and 9 were in the knowledge or control group. This leads to the suspicion that some of those subjects in the feedback groups used the vacation excuse as a polite way of refusing further participation. We think this was

because more is required of people in the feedback groups than in the control and knowledge groups, and this may account for the relatively greater drop-out rate in the feedback groups.

The treatments (self-comparison feedback, social-comparison feedback, clock control, and control) were administered in the same way as in experiment 3. In experiment 3, the clocks were connected to the furnace to measure the on-time of the furnace. For the present summer experiment, the clocks were reconnected to the air-conditioner. In the homes in this study, air conditioning accounts for approximately 40% of the total electric usage. Pretreatment consumption was from July 1 to July 23, 1976. The treatment period was from July 23 to August 27, 1976.

The group means are presented in Table 3. Because of the differential drop-out rate among the groups and the way in which some households from experiment 3 were assigned to experiment 4 groups, the original winter randomization process was compromised. However, it should be noted that the control group has the lowest pretreatment consumption mean which seems to rule out one of the problems with the large withdrawal rate from the experiment. One might have argued that those who did not want to continue participation were either less interested in conserving, less able to conserve, or less eager, in general, to be part of the experiment. This implies that those left in the feedback groups formed a corps of highly motivated individuals who were very interested in conserving energy. Apparently, this is not the case because the feedback groups began the experiment with higher consumption than the control. However, statistically there is no real difference among the pretreatment consumption means, $F(3,67) = 0.91$, $p < .44$.

An analysis of covariance was performed on consumption during the

Table 3

EXPERIMENT 4: AVERAGE DAILY ELECTRICITY CONSUMPTION (in kWh)

<u>Descriptive Statistics</u>	<u>Condition</u>			
	<u>Self Comparison Feedback</u>	<u>Social Comparison Feedback</u>	<u>Clock Control</u>	<u>Control</u>
Pretreatment score				
<u>M</u>	54.75	55.38	51.22	47.12
<u>SD</u>	15.10	17.28	18.91	15.36
<u>n</u>	16	17	15	23
Raw score during treatment				
<u>M</u>	55.96	56.12	58.74	51.92
<u>SD</u>	11.74	13.77	14.56	16.29
Adjusted score during treatment ^a				
<u>M</u>	54.06	53.75	59.39	55.55
<u>SD</u>	6.32	6.03	8.15	9.78

^aScores adjusted by removing the effect of the covariate, average daily consumption during the pretreatment period (July 1 to July 23, 1976).

treatment period. As explained earlier in experiment 2, covariance adjusts the during-treatment scores on the basis of the pretreatment scores in order to minimize the effects of pretreatment differences. In this study, as in the case of experiment 3, the results may not be statistically significant, but they are provocative. The treatment period was warmer than the pretreatment period, and electricity consumption (for air conditioning) increased in all four groups. However, in the self-comparison group it increased only a fourth as much as it increased in the control group, and in the social-comparison group it increased even less. Still, the differences among groups did not reach the conventional level required for statistical significance ($p < .05$), so one cannot argue too strenuously from these data.

Experiment 5

In the feedback experiments discussed so far, feedback was given fairly frequently, either daily or at least three times a week. Does feedback need to be given this frequently to be effective? To help answer this question, a study was conducted during the winter of 1976-1977. Early in December, 1976, Twin Rivers families living in three-bedroom townhouses (that used natural gas for space heating, water heating, and cooking) were telephoned and asked if they wanted to participate in a study of energy consumption. One hundred ten families had to be contacted in order to find 80 that were willing to participate and that were not planning extended vacations (over three days) during the next few months.

The households in the study were randomly assigned to four conditions with the constraint that there be 20 households per group. One

group was to receive self-comparison feedback daily, one weekly, and one group biweekly. The fourth group in the study was a control group. The households in this group were told that we were interested simply in monitoring their gas consumption by reading their meters once a week for a couple of months. They were asked to continue using gas as they normally would since it was their regular, normal consumption patterns that we were interested in.

On January 10, the feedback phase of the study was supposed to begin. However, that day also marked the beginning of a period of bitter cold weather which was to make that January the coldest one on record. A thick blanket of snow from a recent storm added to the difficulty of moving about outside. Because of this weather, meter reading and feedback was postponed. On January 12, research assistants made an extraordinary effort to read all the meters and give feedback. Not only did they have to struggle with the cold and snow, many of the back gates were frozen shut blocking access to the gas meters. From that experience it became clear that the study would have to be delayed. A letter was mailed to all participants on January 13 informing them of the problem and indicating a new starting date of January 17, weather permitting. As it turned out the feedback phase of the study was not able to get underway until January 25.

Because of the severe weather, a critical shortage of natural gas and other energy supplies had developed in the Northeast. On January 27 the Governor of New Jersey declared a state of emergency and required that a number of conservation measures be taken in all public buildings and schools, including a 65°F maximum thermostat setting in the day and 50°F at night. On January 29 these regulations were extended to all

retail and business establishments and all homes. (The maximum nighttime thermostat setting was 60°F for homes.) Since everyone was obliged to take the same energy conservation actions, any difference that may have resulted from differences in the frequency of feedback among groups would not be realized. This is, in fact, what the data showed: no statistically significant differences in consumption among groups during the day or so after feedback began and before the Governor's executive order, and no statistically significant differences in the six weeks after the Governor's orders.

Although this study was ruined as a feedback experiment, we tried to make use of the data to assess the response to the order to reduce thermostat settings in the home. In the third week of February, all households in the study were called and asked what their daytime and nighttime thermostat settings had usually been during the winter before the Governor's order and what the settings were after the order. Before the order the mean reported daytime setting was 69.8°F (sd = 1.9) and the mean reported nighttime setting was 69.3°F (sd = 2.4). After the order the mean reported daytime setting was 65.8°F (sd = 1.6) and the mean reported nighttime setting was 64.5°F (sd = 3.0). The drop in reported daytime setting was 4.0°F (sd = 1.8) and the drop in reported nighttime setting was 4.8°F (sd = 2.7). Ninety-six percent of the households reported dropping their daytime thermostat setting after the Governor's order, and 94% reported dropping their nighttime setting. These results corresponded very closely to the results of a survey conducted in early February for the Public Service Electric and Gas Company (New Jersey's largest utility) of 389 of their residential customers. Ninety-two percent reported lowering

their thermostats (Wald, 1977).

An estimate of the veracity of the reported thermostat lowering in the Twin Rivers sample was obtained by determining average gas consumption per degree day before and after the Governor's order. For the six weeks before the order (actually, before January 31, 1977), it was 19.9 cubic feet/DD, and for the four weeks after it was 17.9 cubic feet/DD. This represents a reduction in gas consumption of 11.1%. Since about a 3% drop in consumption could be expected for each degree the thermostat is lowered (Socolow and Sonderegger, 1976), the measured reduction in consumption corresponds to an average reduction in thermostat setting of about $3\frac{1}{2}^{\circ}\text{F}$. This is close to the reported drop in thermostat settings, indicating that, on the average, the residents were fairly truthful in reporting thermostat setting reductions. Their accuracy or truthfulness in reporting the actual thermostat settings themselves cannot be determined from these data.

Experiment 6

To follow up on our surveys that showed the importance of the relationship between energy consumption and the need or desire for thermal comfort, we decided to test whether information about ways to keep cool in the summer while saving energy would have an effect on electricity consumption. Reducing air conditioner use is the best way to reduce summer electricity consumption. But for many people, using less air conditioning means sweating more. We hoped that people who were provided with tips on how to reduce air conditioner use and still remain comfortable would be more willing to use less air conditioning and would, therefore, save energy. Furthermore, we reasoned that feedback should be an additional aid to them in their efforts to conserve.

The experiment we designed had four groups that were formed by the combination of two independent variables: conservation and comfort tips (present and absent) and self-comparison feedback (present and absent). Thus one group of residents received both the tips and feedback, one group conservation and comfort tips only, one group feedback only, and one group neither tips nor feedback. Because of the importance of a difficult conservation goal to the success of feedback as a conservation aid (see experiment 2), all households in the study were asked to try to cut their electricity use by 20% during the four weeks of the study. The households that received the conservation and comfort information also received a list of the amount of electricity consumed by a wide variety of appliances and a list of reasons to conserve household energy. (See Appendix B.) They also were requested to write to the experimenters with comments or additional reasons to conserve.

One hundred twenty-one families living in three-bedroom (interior) townhouses in one part of Twin Rivers (Quad III) were called and asked to participate. Eighty-eight households (not planning to take vacations) agreed and were randomly assigned to the four groups (with the constraint that there be 22 households per group). Six subjects subsequently dropped out of the study: three from the information-plus-feedback group, two from the feedback-only group, and one from the control group.

The self-comparison feedback was given three times a week in the same way as in experiments 2 and 5, that is, on a chart taped to the sliding glass patio door. (See Figure 1, ^{p. 20a,} for a sample of the type of chart used.) The conservation and comfort tips were presented in a two-page information sheet, "How to Keep Cool in the Summer AND Save Energy." (See Appendix B for a copy of this sheet.) The ten tips included suggestions to turn

off the air conditioner when leaving the home for more than four hours, to open the windows and turn off the air conditioner when it was cool outside, to close drapes and shades on the sunny side of the house, etc.

An analysis of covariance performed on average daily electricity consumption during the feedback period (July 18 to Aug 15, 1977) showed that there had been no effect of the conservation and comfort information, no effect of feedback, and no interaction between those two variables. The lack of an information effect was disappointing but not surprising. It is plausible that the people who were interested in conserving already were aware of the conservation tips we gave them and that the people who were not interested in conserving disregarded our hints.

The lack of a feedback effect was more disconcerting, especially since we had found feedback effects in other studies. To try to find a reason for this, all the households that had received feedback were called and asked about it. Soon the reason became clear. Many residents said the feedback jumped around too much to be believable. They reported seeing little relationship between their conservation actions and the feedback. Consequently the feedback was ignored. The credibility of the feedback had not been an issue in the successful experiments presented above. The main differences between the feedback given in the different experiments were in the methods of computation and display. In the previous experiments, predicted consumption used in the computation of feedback either was based on a regression model relating consumption to weather or involved a control group correction for changes in weather. In this study, predicted consumption was based on pretreatment consumption per cooling degree-hour. Use of this index simplified calculations but, unfortunately, yielded less accurate feedback scores. Furthermore, in experiment 1 feedback was not displayed

over time, only for each feedback period. Thus swings in feedback over time were less salient. In experiment 2, feedback was displayed over time on a chart, but each feedback score was based on the whole period since the experiment began. Therefore, the feedback, being averaged over longer times, was actually smoother than it would have been if individual feedback periods were used. It appears that in the present experiment both the method of computation and the way it was displayed served to exaggerate the swings in feedback making it less credible. This result, of course, underscores the importance of providing credible feedback.

Experiment 7

The widespread implementation of a residential energy consumption feedback program faces a number of serious problems. One major problem concerns the provision of the feedback. In the field studies mentioned above, feedback was provided to residents by research assistants who went from house to house conveying the relevant information. To do this on a national scale would require a veritable army of feedback givers. A plausible alternate approach is to automate feedback, that is, to provide homeowners with a device that can be installed in their homes and that will automatically provide them with feedback about their energy consumption.

Such a device would obviate several questions. Self-comparison feedback is the reasonable candidate for the type of information this device would supply. Social-comparison feedback would require a fantastically complex communication network among homes. Furthermore, there is no reason to believe that social-comparison feedback would be more effective. Indeed, it might not be as effective as self-comparison feedback. Also,

there would no longer need to be any concern about whether less frequently displayed feedback is less effective. With an in-home feedback device, the display can be continuous. Another question that would be obviated by the device is what happens to consumption in a home when feedback stops being given. Since the device is intended to be a permanent part of the home, residents need never be without feedback.

The particular device that the U.S. Department of Energy chose for us to test was about six inches square and had a red digital display. For two seconds it showed the time of day, and then for the next two seconds it showed the rate of energy use in cents per hour. It should be noted that this information was of a totally different kind from what residents in our previous feedback experiments had been given. The feedback provided by this device did not involve a comparison with predicted consumption, so people could not be given feedback in terms of "% conserved" or "% wasted." Also, it did not involve any adjustment for the effect on consumption of changes in weather. It simply gave information about how much energy a household was using at any given instant in terms of cents per hour.

The experiment with this energy cost indicator was conducted in the Washington, DC, area in cooperation with the Potomac Electric Power Company (PEPCO). The sampling plan employed was the one favored by PEPCO representatives. Rather than sample randomly from their entire population of eligible residential customers, they preferred a stratified random sampling plan that drew an equal number of subjects from each of four usage levels. Each level was composed of customers whose total consumption equaled one-fourth of total residential consumption. More specifically, in the summer of 1977, a pool of 989 households was randomly selected from approximately 378,000 residential customers (not including customers with a special

mailing address, unsatisfactory credit history, or who had not occupied their homes for at least one year). The 989 customers were ordered by their annual electricity usage. Starting from the lowest user, the annual usage of the customers was cumulated until the sum equalled one-fourth of the total kilowatt hours used by the 989 customers. The annual usage of 504 lowest consuming customers had to be summed to achieve this amount. These customers and the range of their usage comprised Usage Level 1. The annual usage of the next 238 customers summed to this amount (Usage Level 2), as did the annual of the next 161 customers (Usage Level 3) and the 86 highest consuming customers (Usage Level 4).

The design of this experiment involved two groups, one that would receive the energy cost indicator and one that would not. Since the desired sample size of 70 for each of the two groups was not divisible by four, it was decided that for each group, 18 customers would be drawn from the lowest and highest usage levels, and 17 customers would be selected from each of the other two (middle) usage levels. Thus, 36 customers were to be chosen from the lowest and highest usage levels and 34 from each of the other two levels.

Two hundred twenty-four customers had to be telephoned in order to obtain 140 who agreed to participate in the study. These were assigned either to a test group (to receive an energy cost indicator) or to a control group in the following way. The families were ordered on the basis of their annual consumption from June, 1976 to June, 1977. Starting at one end of this distribution, households were paired off, and within each pair one household was assigned at random to the test group and one to the control group.

Following the assignment to conditions, the participants were mailed information that clearly explained their role in the study. A short time later, each participating household was again telephoned to arrange a personal interview with them. Six of the families assigned to the test group and one of the families assigned to the control group either moved or could not be reached. Two families in the test group and two in the control groups were dropped (by us) for a variety of reasons (e.g., did not own home, sublet home to students, error in past utility records, etc.). Ten families in the test group and five families in the control group withdrew from the study of their own accord. Thus, of the customers who initially agreed to participate, there were 52 in the test group and 62 in the control group remaining at the start of the test period.

Interviews with these customers were conducted in September and October, 1977. During interviews with control group customers, a questionnaire was administered to collect appliance saturation, demographic, and attitudinal data, and all customer questions were answered. During test group interviews additional matters were covered. The energy cost indicator was demonstrated, and its operation was explained in depth. A location was found within the house for the installation of the device, and a manual describing its operation was left with the residents.

The feedback devices began to be installed in mid-October, 1977. Of the 51 treatment households included in the data analysis, 39 had the device installed by December, 47 by January 1978, and all 51 by February.³ There were 36 control households included in the December analysis, 53 in January, 61 in February, and 62 in March and the subsequent months.

Average daily electricity consumption for each month was analyzed using a multiple regression procedure that tested for the effects of

pretreatment consumption, the treatment (i.e., the presence of the energy cost indicator), and the treatment-by-pretreatment consumption interaction.⁴ Pretreatment consumption was average daily consumption for a two or three month period in the preceding year that encompassed the month being analyzed in the treatment period.⁵ For example, when consumption during February, 1978, was the dependent variable, pretreatment consumption was the average consumption during January, February, and March, 1977. The average of two or three months was used rather than just a single month, because the three-month variable is more reliable.

Group means for average daily consumption for each month of the study are shown in Table 4. The results of the multiple regression analyses are shown in Table 5. In no month was there a main effect of the treatment, that is, no statistically significant difference in consumption between the treatment and control groups. In every month (except May and December, 1978, discussed below) there was a significant main effect of pretreatment consumption, indicating a (strong) linear relationship between average daily consumption during the treatment months and their respective pretreatment periods. This latter result is not at all surprising; consumption in one year tends to be very similar to consumption during the previous year.

The only significant effect involving the treatment was a treatment-by-pretreatment consumption interaction. This effect was found in May [$F(1,109)=4.74, p<.05, R^2=.008$] and December 1978 [$F(1,106)=11.03, p<.005, R^2=.004$]. In these months there appeared to be a deleterious effect of the treatment for the typically higher consuming households. (See Figures

Table 4

Experiment 7: Adjusted Group Means for Average

Daily Electricity Consumption (in kWh)^a

<u>Month</u>	<u>Treatment Group</u>	<u>Control Group</u>
December 1977	35.3	37.3
January 1978	37.6	37.3
February	34.4	34.0
March	28.0	27.5
April	24.1	23.9
May	26.2	24.7
June	33.9	33.6
July	40.3	41.1
August	43.5	43.6
September	30.5	28.9
October	24.2	22.3
November	27.0	26.0
December	31.2	30.3
January 1979	32.9	34.5

^aAdjusted for differences in pretreatment consumption.

Table 5

Experiment 7: F-Ratios and R²s for the
Statistically Significant Effects

<u>Month</u>	<u>Treatment (T)</u>	<u>Pretreatment Consumption (P)</u>	<u>T x P</u>
December 1977		654.30 (.920)	
January 1978		1967.38 (.953)	
February		1831.54 (.943)	
March		1045.99 (.905)	
April		429.87 (.796)	
May			4.74 (.008)
June		471.49 (.807)	
July		378.64 (.773)	
August		336.77 (.755)	
September		310.99 (.739)	
October		466.62 (.812)	
November		1632.12 (.938)	
December			11.03 (.004)
January 1979		4569.50 (.971)	

Note. R²s are given in parentheses.

Note. A p-level of .005 is associated with all the F-ratios except the one for May. That p-level is .05.

2 and 3.) The results of applying the Johnson-Neyman technique to these data indicate that in May, for households with pretreatment average daily consumption greater than 33.1 kWh, those with the energy cost indicator would use significantly more electricity than those without it. The same result was indicated in December 1978 for households with pretreatment average daily consumption greater than 42.5 kWh. These results are very surprising because the worst that might be reasonably have been expected was that providing households with an energy cost indicator would have no impact on their consumption, not that it would have a deleterious effect.

The interaction effect in May and December is quite likely a statistical artifact arising out of the presence of an outlier in the data and does not represent a real phenomenon. In an analysis that involves a least squares procedure (as the present analysis does), outliers have a disproportionately large impact on the shape and location of best-fit regression lines. In Figure 2 the control group observation at about 63 and 27 (x- and y-axis scores, respectively) may be considered an outlier. It sticks out from the general pattern of the data points and causes the regression line for the control group to pivot clockwise. In Figure 3 the treatment group observation in the far upper right corner is an outlier. It causes the regression line for the treatment group to pivot counterclockwise. When each point was excluded from the analysis, the interaction effect disappeared. Only the expected pretreatment consumption effect appeared: $F(1,109) = 624.39, p < .005, R^2 = .848$, for May; and $F(1,106) = 1851.78, p < .005, R^2 = .928$, for December. Little confidence can be placed in the reality of an effect whose existence depends on the presence or absence of a single data point.

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Figure 2. Scatterplot of May, 1978 consumption data.

Figure 3. Scatterplot of December, 1978 consumption data.

The possibility that the energy cost indicator was an effective conservation aid only to households with certain characteristics was explored by looking for a significant interaction between treatment and each of nine demographic and attitudinal variables. One variable was the number of the following appliances that were present in a household: dishwasher, microwave oven, trash compactor, garbage disposal, and carving knife. Perhaps the energy cost indicator would be more effective in a home where there were more appliances. Another variable was interest in conservation. Households were split into two groups on the basis of whether they reported having taken any steps to conserve residential energy. Perhaps only those who had evidenced some interest in conserving would make use of the energy cost indicator. Other variables examined include day and night thermostat settings in the summer, husband's and wife's education, and family income. Two questions about thermal comfort in the summer also served as variables that were examined to see if they exhibited any interaction with the treatment variable.

The consumption in each of four months spaced equally throughout 1978 (January, April, July, and October) was analyzed to see if a treatment-by-household characteristic interaction was present. Out of 36 multiple regression analyses, only one statistically significant interaction appeared. In July, among households where the educational level of the husband was low, those in the treatment group used less electricity than those in the control group; among households where the educational level of the husband was high, those in the treatment group used more electricity; $F(1,94) = 6.59$, $p < .05$, $R^2 = .015$. The nature of the

effect, the small size of the effect, and the fact that it was the only significant one out of 36 analyses, make this result suspect. It is very likely that this result represents nothing more than a Type I error, that is, it is not real.

Another set of variables that was examined in the search for an effect of the energy cost indicator involved electricity demand. Analysis of variance was used to test for a treatment effect in the 30-minute peak demand and the load factor in each of the following months: February, March, April, July, August, and September, 1978. No treatment effect was found.

The results may be summarized in a simple statement: The energy cost indicator had no effect on electricity use. The responses to a questionnaire distributed among treatment group families after the experiment shed some light on why this was the case. The following response illustrates how the energy cost indicator typically was used: "We used the monitor right after you installed it to find out how much each of our appliances was costing us. Then we did what we could to minimize or eliminate some of the costs....Once we made the initial survey and adjustments, we found little further use for the monitor." Another participant wrote: "(We) watched what used the most electricity. We already knew it was electric heating. We were surprised the lights and TV didn't use more. The monitor helped us cut back occasionally, but it generally went unnoticed." Although there were some people for whom the information provided by the indicator was a revelation, most wrote that "it only told me what I already knew -- which appliances use large amounts of electricity." Thus the indicator did not really provide feedback. Basically what it did was to supply the same information that could have been supplied much more cheaply and efficiently

by a list showing the costs of operating household appliances. One resident said exactly this: "...brochures could have told me what used the most electricity, making the energy monitor unnecessary."

It is interesting to note that a few people claimed to have made fairly major changes in their electricity use in response to the indicator, and many reported making a few small changes. In light of the fact that there was no detectable change in electricity consumption, some of these people may have simply been telling us what they thought we wanted to hear, some may have had an exaggerated idea of their own efforts, or the conservation steps that were taken resulted in only trivial reductions in consumption.

Conclusions and Recommendations

The experiments reported above demonstrated that feedback can facilitate energy conservation efforts.⁶ They also demonstrated, and this is very important, that the feedback effect is not automatic. You cannot give residents just any kind of information about their energy use, call it feedback, and expect it to work. And even proper feedback will not lead to conservation in all households. (See Appendix C for a bibliography of residential energy consumption feedback studies.)

We now recognize three Conditions that are crucial for the success of feedback. First, there has to be an initial commitment to energy conservation on the part of residents. Feedback does not motivate people to conserve. In fact, it works the other way around: only motivated people will make use of feedback. And, as experiment 2 showed, the more conservation that is desired, the more conservation that feedback will help to achieve.

The role that feedback plays in energy conservation is like the role a bathroom scale plays in dieting. If an overweight person wants to reduce, a bathroom scale may be a very useful aid in that effort and may greatly

increase the chance that the diet will be successful. For example, if the scale shows that some weight has been lost, the dieter knows that he or she is on the right track and will be encouraged to continue. If the scale shows no loss, or even a gain in weight, the dieter knows that greater effort is needed, that maybe the midnight snacks will have to go. However, if an overweight person doesn't want to lose weight, there is little chance that simply giving him or her a bathroom scale will turn that person into a dieter. Feedback is not magic in either a food diet or an energy diet. It can make it easier for people who want to conserve to do so, and it can even foster and help maintain this motivation, but it cannot in and of itself turn an energy waster into an energy conserver.

A second critical condition in order for feedback to be effective is that it be given in a form that enables residents to evaluate how well or poorly they are doing with respect to their desired level of conservation. It would do little good simply to tell a household that it used 45 kilowatt-hours in the past day, if the residents had no way of knowing whether this amount of consumption was good or bad. If they could have been expected to have used 40 kilowatt-hours, then 45 kilowatt-hours would be bad; it would indicate 12.5% excessive energy use. If they could have been expected to have used 50 kilowatt-hours, then 45 kilowatt-hours would be good; it would indicate 10% conservation. However, if their goal was to reduce consumption 20%, then 45 kilowatt-hours would be good, but not good enough. In other words, feedback will be useful to people only when they can learn from it whether their efforts are having the desired effect.

The third condition that feedback has to meet is credibility. Homeowners must see a rough correspondence between the feedback and their conservation efforts. For reasons discussed above in experiment 6, the feedback given in that study fluctuated a great deal from one time to the next. Residents came

to doubt that it reflected their conservation behavior, and so they ignored it.

Given what is now known about feedback, the kind of information that an in-home feedback device should provide can begin to be specified. Information based on the instantaneous rate of consumption, such as that given by the energy cost indicator in experiment 7, clearly will not be effective as feedback. Since heaters, stoves, refrigerators, freezers, and other appliances that change temperatures generally cycle on and off by themselves, instantaneous rate of consumption gives a confusing and possibly wildly fluctuating picture of energy consumption. Thus it is difficult if not impossible for residents to evaluate this type of "feedback" in terms of what it represents about their conservation efforts.

Some sort of cumulative consumption seems necessary as a basis for feedback. Having said this, a number of questions immediately arise. Over how long of a period should consumption be cumulated -- a day, a week, a month, the time since the beginning of the billing period? Shorter cumulation periods will be more sensitive to changes in consumption, but too much sensitivity can lead to fluctuations in feedback that might reduce its credibility. Perhaps this variable does not make a difference, or perhaps it would be better if a variety of feedback based on all these periods were presented. But maybe too much feedback would confuse residents.

Another important question is whether raw consumption data will suffice as feedback or whether some adjustments to it are necessary. Raw consumption data is simply information about actual energy use over some previous period. An example of this kind of feedback was presented above. It involves telling residents that they used, say, 45 kilowatt-hours during the previous

day. At issue is whether people will be able to evaluate this information, that is, whether they will be able to determine from it if they are achieving their desired level of conservation.

To make such an evaluation, people must have some idea of how much energy they would have consumed if they had not made any effort to conserve. This expected consumption is a function of past consumption during some specified base period and of differences in consumption-related variables between that period and the most recent feedback period. For example, to determine whether the 45 kilowatt-hours used during the previous summer day indicated conservation, residents might try to recall the average amount of electricity they used during a summer day in the previous year. Let's us say they estimate they used about 40 kilowatt-hours then. Are they now justified in concluding that they have wasted energy during the previous day? No, because that day may have been extraordinarily hot, so it was perfectly normal for them to have used more electricity (for air conditioning). In fact, it is possible that they conserved even though they used more energy than in the average day in the previous summer. Thus they would also have to take temperature into account. The adjustments that a resident must make to evaluate raw consumption feedback require a quantity of information and a level of sophistication that relatively few are likely to possess. This suggests that raw consumption data will not be effective feedback and that an in-home feedback device should present information adjusted as discussed above. Of course, this hypothesis could, and should, be tested.

Since temperature is the variable that by far has the biggest impact on consumption, it might be the only variable for which an adjustment needs to be made. The main advantage of temperature-corrected feedback, which

is the only kind that our experiments have found to be successful, is that it makes changes in consumption more clearly attributable to residents behavior. Since temperature is taken into account in such feedback, it is more difficult for residents to dismiss excessive consumption as being due to unusually hot or cold weather.

The complexity and cost that would be introduced by having an in-home device provide temperature-corrected feedback is not great. The only additional hardware required is a temperature probe that would be mounted in an unobtrusive location on the outside of the house and a separate input to the device from the air conditioner and furnace circuits. The additional calculations involved in this kind of feedback would require only minimal additions to the logic circuitry.

Miscellaneous Studies

Reducing Air-Conditioning Waste by a Cool-Weather Signalling Device

Feedback is a way of providing information that tells homeowners when they are consuming too much energy. Presumably, when feedback indicates waste, homeowners take corrective actions. Thus, feedback is a signal that some energy control action is required. In our feedback experiments, subjects usually were told that their best energy saving action was thermostat control. But there are other ways to highlight the importance of thermostat control and to signal when it should be exercised.

One signal that would be useful would tell homeowners when they could cool their houses without air conditioning by taking advantage of cooler outside temperatures. Usually in the later parts of the day, when the sun goes down, the outside temperature actually drops below the indoor temperature, even with the air conditioner on. It is at these times that it may be possible to maintain a house at a comfortable temperature without air conditioning

simply by opening windows.

To take advantage of this free air conditioning requires that people be sensitive to the outside temperature. One of the rules for the proper use of an air conditioner is to keep doors and windows shut when it is operating. Ironically, this decreases the residents' awareness of outside temperature. To the extent that unawareness of cool outside weather leads to wasteful air conditioning, a signalling device to increase such awareness should be an effective conservation tool.

The present study was conducted to test the effects on summer electricity use of both a cool-weather signalling device and feedback. (See Becker and Seligman, 1978, for a complete description of the study and results.) Fifty-eight Twin Rivers homeowners had to be called in order to obtain 40 who would agree to participate. Homeowner interest in participating in the study was controlled in the following way. During the initial call, we said that we were interested in testing whether a signalling device we had designed would be helpful to people in reducing their energy consumption. Homeowners were told that we were drawing up a list of people who were interested, but since we were having trouble with our suppliers we were not sure how many of the people we contacted would finally get a test device. They were further told that if we did not have enough signalling devices we would choose people at random to receive them. Those who agreed were told that we would get back to them in a few days.

Forty households were randomly assigned to one of four conditions: signalling device only, feedback only, signalling device plus feedback, or neither. No family objected to its assigned condition and apparently there was no resentment about the randomization procedure. Thus, subjects in all groups were equated in terms of their willingness to let a signalling device

be installed in their house.

The signalling device consisted of a 3.8-watt light bulb mounted in a 2-1/2" x 3-1/2" x 3/4" piece of maple-stained wood and covered in blue plexiglass. It was mounted on the side of the wall phone where it could be seen from the kitchen and adjoining family room. The device was connected both to the air conditioner and to a thermostat we installed on the outside wall of the house. When the air conditioner was on and when the outside temperature was below 68°F, the blue light would blink repeatedly. The only way the homeowner could stop the blue light from blinking was to shut off the air conditioner. When the outside temperature was 68° or higher, the blue light was off regardless of whether the air conditioner was on or off.

Between August 10 and August 15, 1977, all signalling devices were installed and all feedback charts put up. From August 15 to September 12, feedback was given every Monday, Wednesday, and Friday. The feedback was computed and displayed in the same way as in experiment 6 reported above.

The twelve meter-reading periods between August 15 and September 12 were divided into two sets based on whether the outside temperature dropped below 68°F, the point at which the signalling device could become operative. Consider the six meter-reading periods during which the outside temperature fell below 68°F. An analysis of covariance (using pretreatment consumption as the covariate) revealed a significant effect due to the signalling device, $F(1, 35) = 4.64$, $p < .04$. Homeowners with the signalling device used 15.7% less electricity than those without (see Table 6). As in experiment 6, and for the same reasons (see pp. 38-39), there was no significant feedback effect, nor was there a significant interaction. During the meter-reading periods when the outside temperature did not drop below 68°F, no significant effects were found.

The results demonstrated that the signalling device was effective in alerting homeowners to a savings opportunity of which they apparently took advantage. The payback period for the device based on the savings achieved in this study would be about two years. State-sensing information systems, such as our signalling device, seem promising sources of energy consumption savings because they focus people's attention on specific conservation actions and do so exactly when these actions are appropriate.

Interestingly, removing the residents from the control cycle by eliminating the signal and, instead, connecting the device directly to the air conditioner would not necessarily make the system more effective. Admittedly, since people might not always heed the signal, there would be a gain if the device automatically turned off the air conditioner as soon as the outside temperature fell below 68°F. However, since there is a lag in time between a change in outdoor temperature and a corresponding change in indoor temperature, there would be a loss if the device automatically switched the air conditioner back on as soon as the outside temperature climbed over 68°F. Obviously, the longer the air conditioner remains off, the greater the savings; therefore it should be left to the residents to remember to turn on the air conditioner again. Another advantage of signalling conservation opportunities rather than automating the system is that consumption is made more salient. This may in turn lead them to conserve energy in additional ways not specifically indicated by the device.

Table 6

Average Daily Electricity Consumption (in kWh)
During the "Blue Light" Period

<u>Descriptive Statistics</u>	<u>Signalling Device</u>		<u>No Signalling Device</u>	
	<u>Feedback</u>	<u>No Feedback</u>	<u>Feedback</u>	<u>No Feedback</u>
Raw score				
<u>M</u>	17.84	18.74	20.19	23.14
<u>SD</u>	5.51	4.04	7.23	12.88
Adjusted score ^a				
<u>M</u>	18.30	18.24	20.61	22.76
<u>SD</u>	2.96	4.50	5.69	6.02

Note. n = 10.

^aScores adjusted by removing the effect of the covariate, average daily consumption during the pretreatment period (June 1 to August 10, 1977).

Automatic Multi-Setback Thermostat

Although some people may appreciate receiving feedback and use it to help themselves control their energy usage, others may be too unconcerned or too lazy to make use of feedback. However, it may be possible to convince this latter group to let an automatic device do the work of saving them energy and money. Day/night thermostats were designed to do just that. They allow the user to drop the temperature of the house by a specified number of degrees for a specified length of time during a 24-hour period. It is usually used by the homeowner to drop the temperature of the house (in the winter) just after the time the family typically goes to bed and to return it to a daytime level just before the time the family typically arises in the morning.

Day/night thermostats clearly lead to a savings in energy, but they do not take full advantage of the possible savings. They would be even more effective energy savers if they allowed users to make a second temperature setback during a daytime period when they are regularly out of the house. A second setback would allow the temperature of the house to drop very low, even lower than a comfortable nighttime temperature, just after the family left for work and school, and to return to a comfortable level just before they returned.

There is another important drawback to the currently available day/night thermostats. Their design and function ignore an important psychological consideration that greatly reduces consumer acceptability. A thermostat's clock-linked cycles are more rigid than a family's schedule. For example, people sometimes go to bed later than they ordinarily would. This requires them to reset the time cycle of the thermostat, then reset it the next day to the ordinary cycle. Psychological research suggests that in order for such a device to become attractive to people, they must feel they have

genuine control over it. This means that they should be able easily to override the normal cycle and impose their temporary needs on it. Day/night thermostats now on the market provide no simple way to temporarily override the cycles.

Because the thermostat we envisioned did not exist, we built one. Originally the design was simply a functional one, realized only on paper. However, a very capable student, Herb Mertz, actually built several versions of the thermostat as part of an engineering class project, which enabled us to do some testing of the psychological acceptability of the actual thermostat. The final version of the thermostat permitted both a night and day ("empty house") setback, with separate temperature levels for each setback, and had a flexible override system. The homeowner could choose to override the normal cycle for a desired period of time, and at the end of that period the thermostat would automatically return to its normal energy-conserving cycle. The key point here is that the thermostat would automatically operate to save energy. (See Mertz and Darley, 1976, for a complete description of the thermostat.)

This thermostat reverses the conditions for homeowner participation in energy control. With a standard thermostat, residents must take some action (namely, lower the setting in the winter or raise it in the summer) in order to reduce energy use. If, for example, they forget to turn down the thermostat when they go to bed, energy will be wasted. Only when they remember, or feel so inclined, will residents make appropriate changes in thermostat setting. The thermostat we built, however, automatically maintains the minimum desired temperatures during various periods of a day until the residents decide to intervene and use additional energy. Thus, with this thermostat, residents do not have to act in order to use less energy. Quite the opposite;

they have to make a conscious decision and then act in order to use more energy.

Our studies were designed to answer two critical questions: (1) how much savings can actually be achieved using this fairly sophisticated thermostat, and (2) will people be willing to live with this automated thermostat (which perhaps will be seen as a Frankenstein monster by some people)? Five houses were outfitted with the thermostat during parts of the winter of 1975-76. With these houses we worked out hardware difficulties. Because of continual mechanical adjustments it was not possible to accurately estimate savings. Through the use of a chart recorder in one house, however, we did not get profiles for house temperature variation during a night setback. Analysis showed that gas consumption was down 25% for the 24-hour period, which included an 8-hour setback of 10°F (from 70° to 60° on a 35°F night).

The first full scale field test of the thermostat occurred during the summer of 1976 in 10 centrally air conditioned three and four-bedroom Twin Rivers townhouses. In each home a digital clock was connected to the air conditioner to measure its on-time. The clock was placed in the kitchen near the telephone. Each evening during the study, residents were called by a research assistant and asked to read the amount of time accumulated on the clock. They then pressed a button that reset the clock to zero, starting the next 24-hour period. Air conditioner use was recorded daily in this way from July 27 until September 15, 1976, when the study ended.

The thermostats were installed around August 17. Several days before this, families were given reference sheets briefly describing the purpose and operation of the thermostat. Upon installation, the residents received in-depth instructions about its operation.

To assess the effect of the thermostats, air conditioner on-time during the three weeks before the thermostat was installed was compared with on-time

during the four weeks after it was installed. To adjust for the differences in the length and temperature during the two periods, the amount of time that the air conditioner was on in each period was divided by the number of cooling degree-hours in that period.

Because of a continuing problem with an air conditioner clock, one of the ten families had to be dropped from the study. The data from another family indicated an increase in consumption after the thermostat was installed. Interviewing that family uncovered a major error in the setting of their programmed daily temperature cycle. Before the thermostat was installed, the family, which was totally out of the house during the day, turned their thermostat up to 90°F. On almost all days, this prevented the air-conditioner from coming on. However, when the Princeton thermostat was installed, a daytime temperature of 77°F was chosen by the family due to a misunderstanding with our installers. At the very least, this demonstrated how the homeowners' understanding of the situation interacted with temperature settings and, consequently, savings.

For the eight families with thermostats that were used appropriately, air conditioner use before the thermostat was installed averaged .0432 hours per cooling degree-hour ($sd = .0133$). After the thermostat was installed, the air conditioner was on an average of .0348 hours per cooling-degree hour ($sd = .0124$). This represented a drop in air conditioner use of .0084 hours per cooling degree-hour ($sd = .0117$), or 19.4%.

Not only did the thermostat save energy, but resident reaction to it was very favorable. Almost all families appreciated the time-temperature scheduling, indicating it would be even more useful for them in the winter. Some families liked the thermostat so much that we had some difficulty in getting them to part with it at the end of the study.

To further explore residents' reactions to the thermostat and to determine the energy savings that could be achieved during the winter, another study was conducted in the winter of 1976-77. This study was conducted in much the same way as the study during the preceding summer. Six Twin Rivers townhouses were outfitted with the thermostat. Natural gas consumption was measured for a month or two before the thermostats were installed in early February, 1977. (The length of the pre-thermostat period depended on how far back we had to go in utility company records to find a non-estimated gas meter reading for a household.) Gas meter readings were made during the time the thermostats were in place. The study was concluded in late February.

In the pre-thermostat period, the households used an average of 13.2 cubic feet of natural gas per degree-day (sd = 3.3). While the thermostats were in place, households used an average of 9.1 cubic feet per degree-day (sd = 2.4). This represented an average reduction in gas use of 4.1 cubic feet per degree-day (sd = 1.7), or 31.3%.

In comparing the results of the summer and winter studies, it appears that the thermostat was more effective in reducing gas consumption in the winter than air conditioner use in the summer. This is not necessarily the case. In both studies, we attempted to find families who would be entirely out of the house most of the day so that the effectiveness of the daytime "empty house" setback could be gauged. For our summer study we could find only one such family. All the families in the winter study were gone from the house during the day. Thus, the difference between the studies in reduced energy consumption may simply be a reflection of the increased use that was made of the daytime setback in the winter study.

To summarize, our automatic multi-setback thermostat was very successful. The energy savings that were achieved had two sources: first, and obviously, the setbacks themselves; and second, a feature we had included in our discussions with the homeowners. As will be remembered, people were asked to maintain their houses at reduced temperature settings during certain times. Building on this, we simply "negotiated" with people lower values for the normal setting of the thermostat when we installed it in their homes. If the setting proved too cold, (in the winter) or too hot (in the summer), they could then adjust it. Perhaps because they perceived that they had this control, most of the homeowners tolerated the lower settings. This contributed considerably to the substantial savings that were obtained.

A final comment. Many studies of the potential savings that would result from various thermostat settings for various periods of time in different climactic regions of the country are computer simulations (see Pilati, 1975). We wish to emphasize that it is important to document the actual savings obtained when homeowners are asked either to keep their home at various temperature settings or to use an automatic thermostat to switch settings. Residential energy consumption does not take place in a vacuum. People live in homes and the attitudes and behavior of homeowners must be taken into account.

Utility Company Billing Plans and Energy Consumption

In this era of high energy costs, many utility companies have instituted what they call "budget," "equal monthly payment," or "average payment" plans to soften the impact of large bills. These plans are offered so that payment for electricity for months of peak usage can be spread out over a longer time period. There are several variations on these fixed monthly

payment plans, but typically they work as follows: The utility company estimates the total yearly cost of energy for a particular household and divides that total by twelve to arrive at the fixed monthly payment over the course of a year. At the end of the year, customers "settle up" with the company for any discrepancy between their actual energy costs and their payments.

It appears that there is a great deal of satisfaction with these plans among both utility company executives and the customers who use them. Some utility company executives report that the number of complaints over high bills, "faulty meters," and rising rates dropped precipitiously after customers come on the plan. More companies throughout the country are adopting these plans and the number of people in existing plans is increasing steadily. Enrollment figures suggest that once customers are on average payment plans, very few quit them.

Although energy conservation was not a matter that was pertinent to the institution of the average payment plans, these plans may have an impact on consumption. Of particular concern is whether it is wise, from an energy conservation standpoint, to soften the impact of large bills. Certainly the financial consequences of consumption are less direct under an average payment plan. Also, to the extent that consumers see large bills as signalling excessive, avoidable consumption, it is probably not wise to eliminate this information. As it turns out, customers on the average payment plans do receive information about actual energy use and costs on their bills. However, since they pay a fixed amount each month, this information may be less salient or important to them.

To determine the effect on energy consumption of average payment plans per se, that is, unconfounded by the factor of self-selection into the plans,

requires the random assignment of customers to average payment and conventional payment plans. This, however, is something that the utility companies we contacted were unwilling to do, fearing that it might inconvenience or displease their customers and add to their own bookkeeping and administrative responsibilities. Fortunately, the important practical question, given the voluntary nature of almost all participation in average payment plans, is not whether the plans per se affect energy consumption but whether they affect the consumption of those who ask to go on (and do go on) the plans compared to those who do not ask (and do not go on). To answer this question the plans of two utility companies, the Potomac Electric Power Company (PEPCO) and the Commonwealth Edison Company (CECO), were examined. These plans are typical of many around the country.

In each study the electricity consumption of customers on the average payment plan and of customers on the conventional "pay as you go" plan was examined for two periods, one before and one after the average payment plan customers went on the plan.

With the nonequivalent control group design, the similarity of the treatment and control groups is a critical variable; the greater the similarity, the more effective the control. This is particularly true in the case in which membership in the two groups is based on self-selection. With this in mind, an attempt was made to choose control group members on a basis that would increase the likelihood of similarity with treatment group households. Rather than sampling randomly from households not on the average payment plan, it was possible in the PEPCO study to select the neighbors of households on the plan as subjects for the control group. In the CECO study, the first appropriate household not on the plan following a treatment household in the company's billing records was chosen as a control. This

was often a next door neighbor and always a household in the same neighborhood.

The summers of 1975 and 1976 were chosen as the pre- and post-treatment periods for several reasons. Previous research on residential energy consumption indicated that treatment effects are most likely to be detected in the summer. This occurs because the discretionary use of energy, primarily electricity for air conditioning, is greater then. Thus, in the summer residents have the greatest opportunity for cutting back energy use. Since the effect of an average payment plan, if indeed there was one, may very well have been small, it was decided to focus on summer electricity consumption to maximize the chance of detecting an effect. Summer was chosen as the season used for the pretreatment period as well as the posttreatment period in order to minimize the problem of consumption differences across different seasons. Seasonal consumption rather than monthly consumption was examined because of its greater reliability.

These two summers were highly comparable in terms of temperature. (The summer of 1976 was a little cooler in both the Washington, DC, and Chicago areas.) According to National Weather Service records, they were the most similar adjacent summers of any in at least the preceding five years.

A search of PEPCO's computer files identified 221 residential customers (excluding apartment dwellers) who 1) were in their homes at the beginning of the summer of 1975 2) came on the plan sometime between the summers of 1975 and 1976 (i.e., between October 1, 1975 and May 31, 1976), and 3) remained on the plan through the summer of 1976. Consumption records were obtained for these households as well as for their next door neighbors on each side. Some adjacent households could not be used as controls because they, too, were on the plan, or because they were small commercial establishments, apartment buildings, new houses not completed in the summer of

1975, and houses whose ownership changed between the summers of 1975 and 1976. The final sample consisted of 90 treatment households that had both next door neighbors suitable as control households, 74 that had one neighbor suitable as a control, and 57 with no neighbors acceptable as control households. Thus the PEPCO study involved 221 households that asked to be enrolled (and were enrolled) on the plan and 254 control households.

In the CECO study, because of the costs involved in identifying and obtaining the consumption records for every eligible treatment household and control, only residential electric space heating accounts were checked. Three hundred such customers (including apartment dwellers) were randomly selected from among those who came on the plan between January 1, 1976 and May 31, 1976. (When the computer search was made, the records for earlier months had been purged from the computer files.) Printed out along with each selected treatment household was the next customer listed in the records as not having come on the plan during this time. These customers were to serve as the controls. When the consumption records for all households were examined, it was found that most of those who had come on the plan did so soon after moving into their homes. This meant, unfortunately, that there was no record of summer 1975 consumption for them, and they had to be dropped. Some subjects were also lost because they moved before the end of the summer of 1976. The final CECO sample consisted of 42 treatment households that had 32 acceptable control households.

Average daily electricity consumption was analyzed using a 2 x 2 repeated measures analysis of variance in which group (treatment and control) was crossed with year (1975 and 1976), the repeated measure. Table 7 presents the cell means and standard deviations for the PEPCO data, and Table 8 presents that information for the CECO data. Since the subjects in the study were not randomly assigned to the groups, a significant difference between

Table 7

PEPCO Study: Means and Standard Deviations of Average Daily Electricity
(in kWh)
Consumption_A for the Treatment and Control Groups for the Summers of
1975 and 1976.

<u>Group</u>	<u>Year</u>	
	<u>1975</u>	<u>1976</u>
Treatment		
<u>M</u>	49.38	48.47
<u>sd</u>	18.16	18.54
<u>n</u>	221	221
Control		
<u>M</u>	42.58	40.44
<u>sd</u>	18.52	17.37
<u>n</u>	254	254

Table 8

CECO Study: Means and Standard Deviations of Average Daily Electricity
 (in kWh)
 Consumption_A for the Treatment and Control Groups for the Summers of
 1975 and 1976.

<u>Group</u>	<u>1975</u>	<u>1976</u>
Treatment		
<u>M</u>	43.34	40.14
<u>sd</u>	23.67	21.27
<u>n</u>	42	42
Control		
<u>M</u>	37.10	35.94
<u>sd</u>	22.37	21.54
<u>n</u>	32	32

the groups would not indicate a treatment effect. The key to a possible treatment effect would be a change in the difference between groups from the pretreatment to the posttreatment period, that is, a significant group-by-year interaction.

The analyses revealed no significant interaction in either study, but there was a significant difference in consumption between the treatment and control groups in the PEPCO study. Customers who asked to be put on the average payment plan used significantly more electricity (48.92 kWh versus 41.51 kWh, or 17.9% more) over both years than their neighbors, $F(1,473) = 20.78$, $p < .001$, $R^2 = .04$. There was also a sizable difference of the same sort between groups in the CECO study (41.74 kWh versus 36.52 kWh, or 14.3% more consumption in the treatment group), but this difference was not statistically significant. The difference in consumption across years was significant in both studies, $F(1,473) = 16.62$, $p < .001$, $R^2 = .002$ in the PEPCO study, and $F(1,72) = 7.46$, $p < .008$, $R^2 = .002$ in the CECO study.

With respect to the existence of a treatment effect, the results of both studies are in agreement: Given the present context of voluntary enrollment in average payment plans, participation in them had no effect on electricity consumption. In neither study was the group-by-year interaction statistically significant; there was no difference between the treatment and control groups in how their electricity consumption changed from the pretreatment period to the posttreatment period.

The conclusion that the average payment plans had no effect on electricity consumption, based as it is on the absence of a statistically significant finding, requires more corroboration than one based on the presence of a statistically significant effect. Several points can be offered to buttress the conclusion. The data of both studies present virtually the same picture. In

each study the treatment group always used considerably more electricity than the control group, and more electricity was used by each group in the summer of 1975 than in the summer of 1976. More directly relevant to the matter of the treatment effect, in both studies there was little difference in how the electricity consumption of the two groups changed from one summer to the next, and in neither study was the difference significant.

When an effect is not detected, the possibility always exists to some extent that the test for the effect was not sufficiently powerful. In the present studies the test for the interaction effect was quite powerful. In the CECO study an interaction effect as small as one accounting for .12% of the variance would have been found to be significant. In the PEPCO study an even smaller interaction effect would have been detected, one accounting for as little as .04% of the variance. This power was derived from the design of the studies, a repeated measures design, and from the sizes of the samples, particularly large in the case of the PEPCO study.

Thus, in summary, in two studies the average payment plan effect was given the best chance to show itself, a sensitive design was employed with reasonable if not large sample sizes, yet in both studies no such effect could be found. This result could mean any of several things. It may be that the payment of a fixed amount each month does not cause average payment plan customers to be less attentive to the information on their bills about actual energy use. However, if it is the case that conventional plan customers do pay more attention to their bills, then the lack of effect of the plan on consumption could mean that the feedback provided by the bills does not help conservation efforts, either because the information on the bills is not useful or because it does not come frequently enough. The result may

also be indicating that consumers are no more sensitive to the impact of several large monthly bills during the year than they are to the overall financial consequences of consumption.

Although there was no difference between the treatment and control groups in how electricity consumption changed across the two summers, in the PEPCO study there was a significant difference between them in consumption itself. This difference, and indeed the difference between the two groups in the CECO study, was sizable and existed in both the pre- and post-treatment periods. The fact that the treatment households tended to be the larger summer electricity users may be part of the reason they asked to be put on the plan. Being on the plan would help smooth out the large bills for that season over the entire year. As for why they used more electricity, there are several possibilities. Perhaps a greater proportion of treatment group houses were air-conditioned, or they may have been larger. It is also possible that treatment group residents were more profligate in their energy using ways. There is no way of determining from utility company records which of these possibilities was the case.

The main effect of year was a small one, smaller than the group effect in either study. Yet because the test for it was more powerful than the one for the main effect of group, the year effect was found to be significant in both studies. The effect was probably reflecting the fact that the summer of 1975 was the warmer of the two and, hence, required more electricity use for air conditioning.

In the future as the practical advantages of average payment plans in terms of customer and utility company satisfaction become widely known, and as soaring fuel costs make the plans increasingly attractive to more and more

customers, the automatic enrollment of customers in average payment plans may become widespread. In some places this is already beginning to happen on a limited basis. PEPCO, for example, automatically puts onto the plan new customers moving into electrically space heated homes. (These customers do, however, have the right to switch back to the conventional "pay as you go" plan.) It may very well be, as in the case when customers choose to go on an average payment plan, that automatically enrolling customers has no effect on energy consumption. However, given the potential for increased consumption if this supposition is not true, it would be wise to confirm it by empirical investigation. Unlike the present studies that employed a quasi-experimental design, studies of the effect of automatic enrollment or mandatory participation in average payment plans would have to use experimental designs.

Residential Energy Knowledge Survey

The finding of a number of studies that feedback can facilitate energy conservation demonstrates the importance of residents' knowledge of their energy consumption. The fact that feedback has been able to help people with their conservation efforts may be indicating that their knowledge is inadequate. Learning about the extent and accuracy of residents' knowledge of their energy use has several benefits: 1) it will give some indication of the amount and type of information that they need; 2) it will help identify myths about energy consumption so that they may be corrected; and 3) it will provide some indication of the usefulness and validity of studies that make use of self-reports of energy consumption.

In late May, 1978, some of the Twin Rivers households that had not participated in any prior study were called. They were asked if they or their spouses would be willing to be interviewed in connection with a survey

we were conducting about residential energy use. Forty-three households agreed and were interviewed early in June. (The response rate was about 70%.)

Most of the respondents, 81.4%, were females. All but one of the families had lived in their homes for more than two years. In 40 of the 43 households there was a married couple. The median age of the husbands was 36, and the median age of the wife was 34. Half of the husbands were college graduates, and 85% had had some college. About a fourth of the wives were college graduates, and 75% had had some college. There were children in 36 of the families; most (24) had two. The median age of the older child was seven and of the younger child, five. Median family income was about \$25,000. About a third of the respondents reported that they routinely discussed utility bills with their spouses; another third said that utility bills were sometimes discussed.

In the households surveyed, electricity was used for lighting and appliances, water heating, cooking, and central air conditioning. Eighty-six percent of the respondents correctly named their electric company, and all but one knew that their electric bill came monthly. All but two (i.e., 95%) knew that the price of electricity had increased since they had moved into their homes, but few knew what the price was. Answers to a question about the cost of a kilowatt-hour ranged from three cents to five dollars. Of the 21 respondents who hazarded a guess, the median answer was 31 cents. The correct answer was about five cents. Only 16% gave answers of ten cents or under.

How much do residents know about the amount or cost of electricity that they themselves use? When asked about their last electric bill (that they received about three weeks before the interview), only 20.9% could recall what it was to within a dollar; 44.2% recalled to within \$5 of the

actual amount; 67.4% recalled to within \$10. This means that almost a third of the respondents could not guess the amount of their last electric bill to within \$10. The biggest underestimate was almost \$32 and the biggest overestimate was over \$21.

Not surprisingly, the accuracy of people's estimates of the cost of their electricity consumption was found to decay over time. Only 4.7% were able to estimate to within \$1 what their average monthly cost had been during the non-air-conditioning season (November, 1977 through April, 1978); 27.9% were within \$5, and 58.1% were within \$10. Estimates ranged from over \$28 too little to over \$38 too much. Only 2.3% were able to come within \$1 of estimating the average monthly cost of electricity during the previous air-conditioning season (June through September, 1977); 11.6% were within \$5, and 25.6% were within \$10. Estimates ranged from over \$82 too little to over \$41 too much.

The median over- and underestimates were roughly the same within each of the three billing periods mentioned above. However, it is interesting that the longer ago the period, the greater the percentage of respondents who underestimated costs. For the previous month's bill, 52.4% reported an amount that was too low. For the preceding six months, 53.5% underestimated their average costs. For the preceding summer, a period of eight to twelve months before, 56.1% underestimated their average costs. Possibly this pattern of results was reflecting the "good old days" phenomenon in which memories of past experience are shifted in a positive direction. Although these results are suggestive, it would be wrong to make too much of them, since in no period was there a statistically significant difference in the number who underestimated rather than overestimated their costs.

How much do residents know about the amount of electricity used by various devices in their homes? In many homes, air conditioning accounts for a sizable portion of electricity use. Furthermore, the greatest potential for electricity savings through behavioral conservation measures (in non-electrically heated homes) lies in the reduction of air conditioner use. For this reason it was important to get some idea of the extent of residents' knowledge of air conditioning costs. They were asked how much they thought it would cost to air condition their house to 72°F during a month like July when the average daytime temperature is about 80°F. Their estimates ranged from \$5 to \$150, with a median of \$80. The median is almost twice what it actually would cost (about \$45-\$50).

Although they greatly overestimated the cost of air conditioning, their estimates of the cost of changing the thermostat setting tended to be right on target. Five dollars was the median estimate given of the savings from increasing (or the cost of decreasing) the air conditioner thermostat setting by 1°F from 72°F. However, in the context of their overestimate of total air-conditioning costs, an accurate estimate of absolute savings due to a 1°F change in thermostat setting reflected an underestimate of the relative (i.e., percentage) impact that such a change could have on total costs. If residents are more responsive to the relative impact of thermostat setting changes on electricity costs than they are to the absolute impact, then this result clearly indicates a misperception that is important to correct.

The amount of electricity consumed by various appliances in the home depends both on the amount they use while operating and on the length of time they are in operation. Residents' knowledge of appliance electricity use was assessed by having them rank appliances in terms of the electricity they consumed while operating, and over the course of a month and a year.

Respondents were asked to rank the following common household appliances in terms of how much electricity each used when it was on: hair dryer, clothes dryer, clothes washer, black-and-white television, toaster, 100-watt light bulb, and electric toothbrush. A fourth of the respondents (25.6%) did not correctly rank clothes dryer first. Even on the "warm" setting, a clothes dryer uses about twice as much electricity as the next biggest electricity user (when operating), the toaster. The clothes dryer was not ranked either first or second by as many as 16.3% of the respondents. Respondents (72.1%) greatly underestimated the amount of electricity used by the toaster when it is on. The median rank given was 5, and 62.8% did not come within even one rank of its correct position in the list (namely 2). In the case of the hair dryer (rank 3), 23.3% got the rank correct, but 35.7% missed by more than one place. Most (52.4%) ranked it too low. The opposite was true with respect to the clothes washer (rank 4) and the television (rank 5); most ranked them too high. The rank of the clothes washer was overestimated by 72.1% of the respondents; 18.6% ranked it correctly; 55.8% were more than one rank off. The rank of the television was overestimated by 74.4%; 11.6% ranked it correctly; 37.2% were more than one rank off. Although the median rank given the light bulb was correct (namely 6), only 27.9% of the respondents gave the correct response. As many as 35.9% overestimated its rank, 16.3% by more than one place. The greatest proportion of respondents, 37.2%, ranked it in last place, where the electric toothbrush should have been ranked. The toothbrush uses only about a tenth as much electricity as a 100-watt light bulb while operating. Most respondents, 51.2%, correctly ranked the electric toothbrush, and 79.1% ranked it either 6th or 7th. As many as 12.8% of the respondents seriously overestimated the electricity it uses.

Respondents were given another list of appliances and asked to rank them in terms of how much electricity they used in their homes during the last billing period. The list included electric range, lights, refrigerator, freezer, water heater, clothes washer, clothes dryer, television(s), dishwasher, and a category of "all other uses." Because of big differences among families in their use of some of these appliances, it was not possible to assess the accuracy of all the respondents' rankings. However, engineering studies of the electricity used by these devices in Twin Rivers clearly identified the water heater (~ 650 kWh/month) and the refrigerator (~ 200 kWh/month) as the two biggest users of electricity during the non-air-conditioning season (see Socolow and Sonderegger, 1976). Only 46.5% of the respondents correctly ranked the water heater first; only 58.1% ranked it first or second. The refrigerator was correctly ranked second by 20.9%; only 58.1% came within one place of the correct ranking; 62.8% ranked it too low.

When considering the electricity used by appliances over the course of a year, the air conditioner can contribute substantially to total consumption. A list containing the same appliances that respondents had been asked to rank in terms of monthly consumption was given to them again. However, "air conditioner" had been added to the list. Respondents were instructed to rank the appliances in terms of how much electricity each had used in their homes during the past year. Once again, the water heater should have been ranked first. Only 25.6% of the respondents correctly did so, a marked drop from its ranking for the previous monthly billing period. Only 55.8% ranked it first or second. The correct rank for the refrigerator would be either 2 or 3 depending on the amount of air conditioning used. Only 25.6% gave refrigerator use one of these ranks; 65.1% gave it a lower rank. Air-conditioning was ranked first by 39.5% of the respondents, and second and third by 25.6%.

Several of the questions that were asked about electricity were also asked about natural gas. Gas was used only for space heating. Almost all of the respondents, 90.7%, correctly named their gas company, and all but two knew that their gas bill came monthly. All knew that the price of gas had increased since they had moved into their homes, but as in the case of the price of electricity, few knew the price of gas. Answers to a question about the cost of a therm (roughly one hundred cubic feet) of gas in their most recent billing period ranged from two cents to \$30. Of the 19 respondents who gave an answer, the median amount was 50 cents. The correct answer for this group of households ranged from \$.57 to \$1.92. There was no single answer that was correct for all households; unlike in the case of electricity, the more gas that was used, the cheaper it became (per therm used). The answers of 34.9% of the respondents were within one dollar of the correct answer.

Residents were somewhat more accurate in estimating their last gas bill than their last electricity bill. This was very likely due to the fact that the gas bill had come about a week before the interview, but the electricity bill had come about three weeks before. Over a third (37.2%) were able to recall the amount of the bill within one dollar; 41.9% were able to recall it within \$5. Only 53.5% came within \$10 of the correct amount, even though the bill had arrived no more than a week before. Since their last bill was for gas used during May, the month by which or in which furnaces were turned off, respondents were almost as accurate in their estimates of the average amount of gas bills during the non-heating season: 16.3% were within \$1 of the correct figure; 48.8% were within \$5; 53.5% were within \$10. (The monthly cost of gas in the non-heating season was not zero; the median charge was \$6.31. About four to six therms were used per

month by the pilot light, and a few families had installed gas barbeque grills that were used in the summer.)

As in the case of electricity, respondents' estimates of the cost of their gas consumption became more inaccurate over time. Not one was able to estimate the average winter gas bill within one dollar; 25.6% came within \$5 of the correct amount; 48.8% were within \$10. Unlike with electricity, most (70.7%) overestimated the average bill. The median estimate was \$6.24 too much.

Although most respondents overestimated their winter gas bill, most (71.8%) underestimated (by a very similar amount, \$6.34) the cost of keeping their homes at 68°F for one month during a month like January, when the average outdoor temperature is about 30°F. The estimate of only one respondent (2.3%) was accurate to within one dollar; 23.3% were within \$5; 39.5% were within \$10. The cost of a 1°F change in thermostat setting under such conditions would range from about \$.90 to about \$2.25 (median = \$1.46) in the households surveyed. Most (82.5%) overestimated the savings that could be achieved by a 1°F decrease in thermostat savings, and even more (87.8%) overestimated the penalty for increasing thermostat setting 1°F. The median difference between estimated and actual savings from a 1°F setback was \$2.79; the median difference between estimated and actual costs for a 1°F increase was \$3.54. Thus, there was a considerable degree of overestimation of the relative (and absolute) impact of thermostat setting changes on gas costs. This was just the opposite of what was found for air-conditioning costs in the summer.

Another type of question that residents were asked was whether they

found the information currently provided on their utility bills helpful in planning their energy use. Only 20.9% found it helpful. However, when asked what information should be added to the bill to make it more useful, almost none of the respondents had any suggestions to offer.

Another two areas in which people's knowledge is important for energy conservation are those of the costs and the benefits of conservation. How much do residents know about the costs and benefits of improving the energy efficiency of their homes? Respondents were asked how much they thought the average contractor would charge them to make five modifications to their homes. These modifications included such things as caulking cracks around windows and adding six inches of insulation on the attic floor. They were chosen because they had been found by experiments in Twin Rivers to be cost-effective conservation measures. (See Harrje, 1978.) The actual cost of the modifications was \$450. However, 78.0% of the respondents overestimated the cost by \$50 to \$1550. The median estimated cost was \$600. The opposite error was made with respect to the benefits that respondents thought would be obtained. Most of the respondents, 55.8%, underestimated the savings. The modifications would lead to a savings of about 18% on winter heating bills. The estimates of only 20.9% fell within the 13% to 23% range. Almost half of the respondents (48.8%) thought the savings would be 10% or less.

There are several conclusions that may be drawn from the results of this survey. It should be kept in mind that the respondents were well-educated, middle to upper middle class people who, if anything, could be expected to be more aware and knowledgeable than the average American about the matters covered by the survey.

The general conclusion is that most people do not have a good idea of

how much energy they use in their homes or even of how much they pay for energy. Perhaps if they did, feedback would not be needed as a tool to help people trying to conserve. With respect to studies that depend on self-reports of energy consumption rather than actual measurements, this conclusion implies that the results of such studies might be misleading and should be used with caution.

Another conclusion is that most people have inadequate knowledge about the impact of various energy-using devices on total consumption. This is a serious problem because residents need such knowledge in order to take effective conservation actions. For example, turning off unnecessary lights is a very visible, common conservation practice. However, in Twin Rivers, a family would have to keep all its lights off for more than 24 hours in order to save the amount of energy that could be saved by running the air conditioner one hour less. The survey showed that many residents were not aware of the extent of the disparity between the electricity used for lighting and air conditioning. This misperception might have led them to feel satisfied with simply turning off a few lights. In this case, lack of adequate knowledge can deflect people from the more effective conservation actions. To take another example, the Twin Rivers resident spends more money on water heating than on space heating. Putting a jacket of insulation around the water heater would reduce its electricity use by more than 10% and would pay for itself in a year (Socolow, 1978b). However, as the survey showed, many did not know that the water heater consumed so much energy, and so they are less likely to take this step.

So far the effect to educate residents about the energy consumption of household devices has had no serious focus. Typically, residents are given information about the consumption of such things as electric carving

knives, can openers, and toasters right along with information about the consumption of refrigerators and air conditioners. Perhaps it is time to separate the wheat from the chaff, that is, to develop an educational message that stresses just three or four points about the appliances and devices that have the biggest impact on residential energy use. A concerted effort to hammer home these few points may have a more practical positive effect than a more diffuse effort to provide a wider array of information.

Another conclusion that may be drawn from the survey is that many people seriously overestimate the costs and underestimate the benefits of improving the energy efficiency of their homes. Conservation through improved energy efficiency has many advantages as a solution to our country's energy problems. Not only is it effective and economical, but it does not interfere with residents' comfort as do some conservation practices. This is a particularly important point in light of the findings of our surveys of attitudes and energy consumption: resident comfort plays a crucial role in residential energy consumption. (See surveys 1, 2, and 3, above.) The success of efforts to encourage people to improve the energy efficiency of their homes will be jeopardized unless their misperceptions of the costs and benefits of such conservation actions are corrected.

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Footnotes

1. In the climate in which the present research was conducted, if a family preferred to keep its home at 72°F, even a 10°F drop in thermostat setting in the winter (when outdoor temperature is, say 32°F) would lead only to a fractional decrease in gas consumption because a lot of energy is still needed to keep the house at 62°F. Alternately, a 10°F increase (from 72°F) in thermostat setting in the summer (when outdoor temperature is, say 82°F) would lead to a large decrease in electricity consumption because electricity use for air conditioning would be totally eliminated.
2. Each weekday, for one month prior to the start of feedback, the electricity meter was read at each home by a research assistant. Our purpose in this was to model each house's electricity consumption in terms of various weather indices, e.g., temperature, humidity, solar flux. Essentially, this meant attempting to fit a regression line to predict electric consumption from some composite weather index. As it turned out, temperature alone was a good predictor of electricity consumption. Thus, during the feedback period we were able to predict how much electricity each household would use in a particular day, once we determined the average hourly temperature that day.
3. The energy cost indicator in one of the 52 test households that started the study broke after a couple of weeks. The homeowner wanted the device removed and, consequently, this household was dropped from the analysis.
4. The primary concern of this study was whether feedback of the sort presented by the Fitch Energy Monitor helps residents reduce their electricity consumption. In other words, is there a treatment effect? A statistical analysis of electricity consumption data for the treatment and control groups for the treatment period, using either an analysis of variance or multiple

regression procedures, could test for this effect alone and thereby provide evidence that would help answer the question above. However, this simple, apparently direct, approach has a number of drawbacks. The power of the test of the treatment effect is low compared to that of the approach is to be discussed below, and there is no test of any interaction effects involving the treatment factor that could provide further insights into the operation of that factor.

Both of these drawbacks are eliminated by including a second factor, pretreatment consumption, into the statistical design. There is a very large correlation in people's energy consumption in monthly or seasonal periods from one year to the next. Stated in English this means that over the years for comparable time periods people tend to consume the same amount of energy in their homes. A statistical consequence of this fact is that a large part of the variation in a sample's energy consumption can be accounted for by the variation in its consumption for the same period the year before. By entering pretreatment consumption as a factor in the analysis, a large part of what otherwise would be considered unexplained or error variance becomes accounted for and the error term is correspondingly reduced. The test of the treatment effect involving this substantially reduced error term is much more powerful than the test with the "unreduced" error term that occurs in an analysis where only the treatment factor is included.

The inclusion of pretreatment consumption as a factor in the statistical design also permits the test of a treatment-by-pretreatment consumption interaction effect. It is conceivable that feedback may be much more helpful to the large consumers because they have more "fat" they can cut out of their energy budget. This consideration suggests the possibility of a feedback-by-pretreatment consumption interaction. There are other plausible considerations that also raise the possibility of an interaction effect. To repeat, only by

including pretreatment consumption as a factor in the design is it possible to test for such an interaction effect.

The statistical analysis used in the present study was a multiple regression analysis that tested for the effects of pretreatment consumption, the treatment, and the treatment-by-pretreatment consumption interaction. The procedure (see Kerlinger & Pedhazur, 1973, pp. 258-259) first tests whether the interaction accounts for a significant increment in the proportion of the variance in the dependent variable beyond that accounted for by the main effects. If it does, neither of the main effects is tested. Instead, a regression line for each group is calculated and the Johnson-Neyman technique is applied to establish regions of significance. If the interaction is not significant, then the main effects are each tested by determining whether each accounts for a significant increment in the proportion of variance in the dependent variable beyond that accounted for by the other main effect.

The rationale behind this procedure is as follows. If there is a significant interaction (particularly a disordinal interaction), then a description of the feedback effect requires that a qualification involving pretreatment consumption be mentioned. There may be a significant effect of feedback but only for consumers with particular levels of pretreatment consumption. In this case it makes no sense to talk about a main effect of the treatment, that is, an overall or general feedback effect, and therefore it makes no sense to test for such an effect. This is also true for the other factor involved in the interaction. If, on the other hand, the interaction is not significant, it is dropped from consideration, and any variance apparently attributable to it is pooled with the error variance. Then the only effects tested are the two main effects.

5. The pretreatment months are not the same for all the households. Some families have their meters read earlier in the month, some in the middle, and some late in the month. So a June 7 reading date for example, represents the second reading for a period that primarily reflects May's consumption, while a June 21 reading date represents the second reading for a period that primarily reflects June's consumption. A meter-reading period for a given household is now labelled with the month that contributes the most days to that period. For households whose meters are read around the middle of the month, two months (rather than three) comprise the pretreatment period. For example, if a meter was read on May 15, June 15, and July 15 during the pretreatment year (1977), pretreatment consumption for that household for the analysis of June 1978 consumption was average daily consumption over the two-month period from May 15 to July 15, 1977. For households whose meters are read around the first (or last) part of the month, three months comprise the pretreatment period. For example, if a meter was read on May 7, June 7, and August 7 during the pretreatment year, pretreatment consumption for that household for the analysis of June 1978 consumption was average daily consumption over the three-month period from May 7 to August 7, 1977.

6. The argument has sometimes been made that the positive findings of feedback experiments are not due to a feedback effect at all but rather to the so-called "Hawthorne effect." The argument is that the households receiving feedback are responding not so much to the feedback per se but to the implicit demands of the experimenter to conserve and to the increased attention focused on them. However, demand characteristics and attention effects clearly cannot account for the differences that appear between the feedback and no-feedback groups. For example, in experiments 1 and 2, there were no implicit conservation demands made by the experimenter. The demands, or rather, requests to conserve were explicit and were the same for the treatment

groups not receiving feedback as for the treatment groups receiving feedback. All households in both studies had their electricity meters read with equal frequency. Furthermore, in experiment 2 all the households had charts that were marked with equal frequency. Thus, since demand characteristics to reduce electricity consumption and attention paid to subjects was the same for all groups, the effects that were detected in these studies cannot be attributed to these factors.

Other evidence that the feedback effect is not simply a matter of attention or demand characteristics comes from the unsuccessful feedback studies. For example, no feedback effect was found in experiment 6 or in the blue-light signalling device experiment (see pp. 55-59). However, if the feedback effect found in successful feedback studies were nothing more than a "Hawthorne effect," then a feedback effect should have appeared in these experiments, too, because they were similar to the successful studies in terms of the amount of attention that was focused on the participants and the appeals for conservation that were made.

Another argument against the results being due to demand characteristics is based on the experience accumulated by the authors in doing field studies in energy conservation. The subjects in our studies have been "real" people living in the "real" world, not college sophomores spending an hour in a laboratory. To conserve energy in the home by behavioral means, e.g., turning off the air conditioning, often involves some degree of discomfort and inconvenience. Knowing how difficult it is to get residents to conserve, it is difficult for us to take seriously the idea that our subjects put themselves out in this way for weeks at a time simply because they thought we expected them to or because they thought it would make us happy.

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Appendix A:

Project-Related Publications and Convention Presentations

Publications:

- Becker, L. J. Reinterpreting the motivational effects of feedback and goal setting on performance: A field study of residential energy conservation. Dissertation Abstracts International, 1977, 38 (6-B), 2935.
- Becker, L. J. Joint effect of feedback and goal setting on performance: A field study of residential energy conservation. Journal of Applied Psychology, 1978, 63, 428-433. Reprinted in C. M. Franks and G. T. Wilson (Eds.), Annual Review of Behavior Therapy, 1979 edition. Larchmont, N. Y.: Brunner/Mazel, in press.
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Manuscripts Under Review:

Becker, L. J., Rabinowitz, V., and Seligman, C. Evaluating the impact of utility company billing plans on energy consumption.

Becker, L. J., Seligman, C., Fazio, R. H., and Darley, J. M. Relationship between homeowners' attitudes and energy use.

Convention Presentations and Meetings:

Seligman, C., and Fraker, H. Energy and Behavior. Co-directed workshop at the meeting of the American Institute of Architecture, Washington, D. C., December 1975.

Seligman, C., and Darley, J. M. Feedback as a means of decreasing residential energy consumption. Paper read at the meeting of the American Society for Heating, Refrigerating, and Air-Conditioning Engineers, Seattle, Washington, June 1976 and at the meeting of the American Sociological Association, New York, New York, September 1976.

Seligman, C. Psychologists in energy conservation. Paper delivered at the meeting of the American Psychological Association, Washington, D. C., September 1976.

Darley, J. M. Psychological factors in residential energy consumption. Paper read at the meeting of the Society of Experimental Social Psychologists, Los Angeles, California, October, 1976.

Seligman, C. Invited participant in Department of Energy workshop on consumer motivation and behavior regarding energy conservation: Identification of R&D opportunities, Washington, D. C., December 13-14, 1976.

Darley, J. M. The human side of energy conservation. Paper given at Department of Commerce, Washington, D. C., December, 1976.

Seligman, C., Kriss, M., Darley, J. M., and Fazio, R. H. Predicting residential energy consumption from homeowners' attitudes. Paper read at the meeting of the Eastern Psychological Association, Boston, Massachusetts, April 1977.

Seligman, C. Chaired symposium entitled "Psychological perspectives on encouraging energy conservation" at the meeting of American Psychological Association, San Francisco, California, August 1977.

Darley, J. M. Energy conservation techniques as innovations and their diffusion. Paper read at the meeting of the American Psychological Association, San Francisco, California, August, 1977.

Becker, L. J. Feedback as an energy conservation strategy. Paper read at the meeting of the American Psychological Association, San Francisco, California, August, 1977.

Convention Presentations and Meetings: (cont.)

Becker, L. J. and Seligman, C. Preliminary evaluation of an energy-feedback conservation program. Paper read at the meeting of the Eastern Psychological Association, Washington, DC, March 1978.

Seligman, C. Why does feedback facilitate residential energy conservation? Paper read at the meeting of the Human Factors Society, Detroit, Michigan, October, 1978.

Appendix B

Informational Materials Supplied to
Certain Subjects in Experiment 6.

How To Keep Cool in the Summer AND Save Energy

Saving energy in the summer does not mean being uncomfortable. If you act on the following simple tips, you can save a considerable amount of energy (and money).

1. Raise your thermostat. You will probably be surprised to find that you can turn the thermostat up several degrees without noticing any difference in the comfort level of your home. Experiment and see how much higher you can set your thermostat and still be comfortable. (Your air conditioner is by far the largest electricity consumer in your home. For example, the typical Twin Rivers household would have to turn off all its lights for almost a day and a half in order to achieve the energy savings that would come from using the air conditioner just one hour less. Each degree you increase the setting saves you roughly 12% of the electricity used by your air conditioner.)
2. Keep windows and outside doors closed when air conditioning your home. You may have to remind children to close the doors quickly as they go in and out.
3. Setting your thermostat lower will not cool your home any faster. But it will cause your air conditioner to work longer, thus increasing your electricity consumption and costs. Whatever temperature you decide on, set your thermostat at that temperature and leave it alone.
4. When leaving the house for two to four hours, set your thermostat at 82°, rather than shutting the unit off. Re-cooling your house would probably use more electricity than maintaining this temperature while you are away. However, if you intend to be gone for more than four hours, it pays to turn your air conditioner off.

5. Be conscious of the outside temperature. When the temperature is comfortable outside, be sure to open the windows and turn off the air conditioner.
6. Close drapes and shades on the sunny side of the house. This can reduce heat entering your home through window glass by 35%.
7. Restrict heat producing activities, especially during the hot afternoons. Consider doing your washing, drying, ironing, and cooking in the cool morning hours or in the late evenings. In that way, your house will be cooler, and your air conditioner will not have to work so hard.
8. Turn off the dishwasher when it reaches the dry cycle. Not only does the dry cycle require much more electricity than the wash cycle, it also adds considerable heat to your house.
9. Make sure no lamps or heat-producing appliances are located near your thermostat. The heat will alter your thermostat reading, thus affecting the comfort level in your home.
10. Keep air conditioner filters clean. Clogged filters make your air conditioning system less efficient and can result in damage to the unit's compressor. Filters should be checked once a month. They should be washed or replaced as needed.

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ELECTRIC APPLIANCE ENERGY USAGE LIST

	Estimated Use*
LIGHTING	
General Household.....	3 kwh per day
COMFORT	
Air Conditioner, central, electric..... (23,000 BTU per hour)	4 1/4 kwh per hour
Electric Blanket, twin.....	1/2 kwh per night
Electric Blanket, double or queen.....	3/4 kwh per night
Electric Blanket, king.....	1 kwh per night
Portable Heater, electric (1,500 watt)....	1 1/2 kwh per hour
Waterbed Heater.....	4 kwh per night
FOOD	
Broiler, portable electric.....	1 1/2 kwh per hour
Coffeemaker, electric.....	1/4 kwh per brew
Deep Fryer, electric.....	1 kwh per hour
Dishwasher, electricity for normal cycle..	1 kwh per load
electricity required for hot water....	3 kwh per load
Freezer, frostless--15 cu. ft.....	5 kwh per day
Freezer, 15 cu. ft.--manual defrost.....	3 kwh per day
Frying Pan, electric.....	1/2 kwh per hour
Microwave Oven (5 minutes).....	1/10 kwh per use
Refrigerator, frostless--16 cu. ft.....	5 kwh per day
Refrigerator, frostless--20 cu. ft.....	6 kwh per day
Refrigerator, partial automatic--12 cu.ft.	3 kwh per day
Refrigerator, manual--10 cu. ft.....	2 kwh per day
Toaster (2-slice).....	1/20 kwh per use
Toaster-Oven, electric portable.....	1/2 kwh per hour
Trash Compactor.....	1/100 kwh per load
Waffle Iron (3 to 4 servings).....	1/3 kwh per use
Waste Disposer.....	1/100 kwh per load
LAUNDRY	
Clothes Dryer, electric.....	3 kwh per load
Steam Iron (hand).....	1/3 kwh per hour
Washing Machine, cold water (50 gallons)..	1/4 kwh per load
electricity required for hot water....	6 kwh per load

[Continued on next page]

*The estimated usages shown are average figures based on electric company tests and industry statistics. They do not apply to any particular installation or manufacturer's product and vary depending on individual operation. One kilowatt-hour (kwh) is 1,000 watts of electricity used for one hour, such as ten 100-watt lamps turned on for one hour.

GROOMING

Hair Dryer (375 watt).....	2/5 kwh per hour
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HOUSEWARES

Clock.....	2 kwh per month
Floor Polisher.....	1/3 kwh per hour
Night Light, (7 watt).....	5 kwh per month
Vaccum Cleaner.....	2/3 kwh per hour

ENTERTAINMENT**

Radio-Phonograph.....	1/10 kwh per hour
TV, Black and White.....	1/4 kwh per hour
TV, Color.....	1/3 kwh per hour
TV, Instant-on Feature.....	From 4 to 43 kwh per month

**Solid-state units use less.

Reasons to Conserve Household Energy

One of our projects is to compile a list of reasons people offer for the need to conserve energy in the home. Below are listed several reasons that other residents have thought of. We would like you to help us by seeing if you could add to this list. Please write your additional reasons and comments on the sheet following the reasons printed below. Keep this sheet for your own reference, and send us the carbon copy in the enclosed stamped self-addressed envelope.

1. The residential sector in the United States consumes approximately 20% of all the energy used in the country. Consequently, if everyone would make an effort to conserve, it would be possible to save a great deal of energy, and thereby significantly alleviate the energy problem.
2. Over 40% of the oil we use in this country every day is imported from other countries, primarily the Arab nations. We now import a larger percentage of our oil than we did at the time of the 1973-74 Arab oil embargo. In order to maintain our ability to make foreign policy without fear of another Arab oil embargo blackmail attempt, we need to reduce our dependency on Arab oil. In the short run, the best way to do this is to conserve energy.
3. Our supplies of fossil fuels to produce energy are finite and are being used at a greater rate each year. While projections for how long our energy resources will last vary somewhat, all agree that we will run out within the next several generations. One of our concerns as parents is to provide our children with as much, and preferably more, opportunity to live productive and happy lives as we had. Over the last hundred years, it is clear, that, in general, parents have been successful in providing their children with a high quality of life. Because of the energy crisis, we have reached a point for the first time where it is not only conceivable but likely that our children, and their children, will live in a less rich world. To forestall this time as long as possible, and to teach our children to cope with less, we must seriously conserve energy.
4. One of the most basic principles of economics is that as a resource becomes scarcer its price goes up. No one needs to tell you how much the price of energy has gone up in the last five years. Indeed, we are all painfully aware that this incredible increase in energy costs will continue for years to come. Conserving energy means saving money and as energy costs increase conservation will mean even greater savings.

On the following page, please list as many additional reasons as you can or comment as much as you would like to about the above reasons.

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